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Intervention versus Inter-Platform Competition: Strategic Industrial Policy and Standardisation

Many innovation and industrial policy documents assign significant growth potential to "smart standardisation". The aim of this contribution is to discuss the complexity of standardisation as a policy instrument beyond the catchphrase. We derive implications on policies from the underlying industrial dynamics that are involved with the emergence of standards. Policy makers are required to weigh up the social costs of standard wars against the risk of making a suboptimal technological choice. It seems that industrial requirements create standards automatically, that standardisation authorities are often re-confirming market trends, and that the role for proactive policies is rather limited.

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Background

The impressive growth of the mobile phone industry and the GSM standard as its initiating and driving factor triggered the inception of the buzzword "smart standardisation" in many innovation policy and industry development documents. Hopes to reproduce this growth stimulus a second time by setting a standard were, however, dashed and the skyrocketing growth of GSM remained unique.

In support of the discussion about standards as an instrument to strategic industrial policy, the following section will discuss the industrial mechanisms that are involved in standardisation. From this we derive a set of criteria that should be met in order to allow standards to become a successful policy instrument. Privately established standards bear a different risk than public standards. The results indicate that many standards tend to emerge automatically, and that the role of standard setting institutions is simply to re-confirm market trends. To use standards as an industrial policy instrument, we claim that standards should be set 1. at an early stage, when no alternative technology exists and the potential for combinatorial innovation is stimulated, 2. when there is a general consensus of market agents that are able to mutually create a critical mass, 3. if the standard is neutral to firm size, and 4. if consumers benefit from the standard in a way that they are not locked in by switching costs.

The concept of "standards"

Standards regulate the interconnection of physical components or information. Standardisation is the process of setting standards.

Standards set principal parameters that ensure that both "sender" and "receiver" of information recognise its specific meaning. For instance, the metric system is a standard competing for dominance with the imperial system. In a broader sense, languages set the meanings of expressions, and thus enable sender and receiver to comprehend the information transmitted. Even currencies are standards that allow the exchange of goods and services in economies. Put more abstractly, a standard is an "interconnection regulation", which allows for the connection and interchanging of components between sender and receiver whatever or whoever they might be. Standardisation is the setting of standards, either by public officials – in consultation with private industry, or through private entrepreneurs.

Standards shape technological development by providing the parameters within which technological change can occur sequentially. Once a technology path has been chosen, sunk costs are high, i.e., the effort required to reproduce the underlying core technology is much smaller than to set up an alternative (*Schumpeter,* 1935). Similarly, existing technologies may provide "modules", whose recombination often leads to innovation. From this perspective it is hardly surprising that similar inventions sometimes occur simultaneously, because innovators use the same or similar inputs. Such "combinatorial innovation" renders technological change dependant on pre-existing technology channels that in themselves are shaped by the parameters set by standards (e.g., the switch from analogue to digital photography). At the same time, the emergence of complementary goods adds utility to existing technologies. For instance, the building of roads in the bicycle boom and the installation of petrol stations to provide farms with fuel created essential prerequisites for the development of the car industry (e.g., *Varian,* 2003, *Ebersberger – Pyka,* 2002).

If innovations occur sequentially, standards shape the paths of technological development in the long run, provide a playground for combinatorial innovation, and attract complementary goods and services.

The establishment of standards has shaped the evolution of technologies and industries for centuries. A first documented effort to formally standardise something occurred in the 1770s in France, with attempts to normalise parts for the weapons industry. Soon many other sectors attempted to copy the production of interchangeable parts, but little progress was to be seen until Henry Ford and the advent of mass production (*Shapiro – Varian,* 1999A). With the emergence of standards, several "standard wars" have evolved in the 20. century, where parallel technologies and their private proponents were competing for dominance. Examples are typewriter keyboards, combustion engines, nuclear power plants, telecommunications equipment, and videotape recording and high-density DVD technologies (e.g., *Shapiro – Varian,* 1999B).

While privately established standards tend to bear the risk of standard wars, public standardisation more faces the challenge of making the right technological choice.

In order to try and avoid the costs from standard wars, policy makers may intervene and set an official standard. A frequently cited successful example was the official implementation of the GSM standard, which also turned standardisation into an often quoted policy instrument that can foster both innovation and growth. Yet the success story of GSM has not been able to be reproduced, perhaps due to the complexity of the underlying mechanisms and the lack of any technological window of opportunity. Both public and private standards potentially lead to substantial social costs, even though the origins of efficiency losses tend to differ. On the one hand, private firms may compete against each over the dominance of one standard they promote over another. The subsequent disappearance of a standard involves costs (e.g., for the development and promotion), or the coexistence brings about opportunity costs from idle economies of scale. On the other hand, if policy makers set a standard they are only in a position to make a technology choice with limited information under political pressure, which also tends to be suboptimal.

Standards can apply to both products and processes. While the former refer to physical parts (e.g., bolts) and increasingly importantly to immaterial goods (interconnection protocols, programming languages, etc.), the latter describes the regulations outlining the way in which a good or a service is produced. If we apply the definition of standards from above as an interconnection norm, process standards are more like models of production procedures than actual characteristics of a good. In the following, we focus on product standards as a policy instrument.

Standardisation creates a network, and is thus subject to the mechanisms of network industries that strongly affect both consumers and producers (e.g., *Economides,* 1996). The bigger the network the more beneficial the participation for both suppliers and consumers. On the producer's side, network industries exhibit substantial sunk costs (such as expenditures for research and development, advertisement, etc.) that lead to economies of scale and scope. Consumers benefit from bigger networks due to positive consumption externalities, because the bigger the network the greater the chance of interaction with another participant. Hence, the utility of a good depends on the number of other participants. Apart from these direct network externalities there are also indirect benefits, which include the greater availability of complementary goods such as spare parts or a bigger second hand market (*Shy,* 2001, *Katz – Shapiro,* 1985).

Standards generate network effects. These include economies of scale and scope on the producers' side, and greater consumption externalities and indirect effects such as a larger secondary market on the consumers' side.

Official versus private standardisation

Standards are an industrial requirement that emerge independently from the decision of whether they should be set by public or private agents.

Standardisation comes into being either by private companies that establish an industrial norm which is sometimes also referred to as a de facto standard, or by a public authority, which typically uses inputs by industrial agents to start the standardisation process. In the following section we argue that both can give rise to social costs in the long run. While privately set standards may lead to competition between standards and standard wars, publicly set standards may distort market outcomes and lead to suboptimal technology choices. These failures may also occur in reverse, but tend to be less common. Notably, rare empirical evidence for the ICT industry shows that the technical contents of formal and informal standardisation are complementary rather than substitutive (*Blind – Gauch,* 2008). This suggests that standardisation is an industrial requirement that is not only necessary, but also seems to occur independently of the decision of whether it should occur via public or private agents.

Privately set standards and compatibility decisions

A standard prevails over a competing standard if its network effects are sufficiently larger. Other technologies which seek to gain from the network effects will join an existing standard, or opt for compatibility. If compatibility is not possible, sunk costs cannot be recouped.

Standards can be the expression of diverging interests. If several technologies exist for which producers incurred sunk costs, a standard defines the technology channel via which producers are able to recoup their investment costs. In many cases firms form coalitions to promote a standard. The prevalence of a standard is determined by network effects. Once a network attains a certain size, a critical mass, the gap between the leading standard and the followers grows too big, and technological competition is not sustainable any longer. The duopoly or oligopoly of standards then turns into a monopoly, a single standard in which all firms compete (e.g., *Sutton,* 1991). If one network eventually succeeds in becoming the dominating standard, the other, incompatible network will leave the market and write off its sunk costs. Hence, "standard wars" may have social costs which increase over the time of the ongoing "inter standard competition", because both consumers and producers invest into the development, promotion and deployment of the standard that eventually fails.

If network effects are insufficient, incompatibility is the preferred strategy, especially by large firms (e.g., *Katz – Shapiro,* 1985, *Cowan,* 1992). Yet, once a critical mass has been obtained, a standard tends to attract other stand-alone technologies. The utility of offering a compatible system and joining a standard increases with network size, and eventually outgrows the incompatibility solution. Put differently, the utility of joining the dominant standard leads to higher profits and prices than if you use the unconnected solution, and firms will tend to join the winning standard (*Economides,* 1991). For instance, IBM DOS was initially incompatible with other systems. Later it was opened up to benefit from network effects, which emerged from the larger market volume available as a result of the newly gained compatibility with Microsoft's DOS. Another example of the incompatibility choice in markets with fast changing technologies is workflow software, where the systems of the three major main providers are not compatible with each other. Similarly, consumers do not gain from indirect effects: software upgrades are only available from cooperating companies, i.e., firms that are in the same network.

Minor events may become reinforced by network effects and tip the technological choice into a particular direction.

Technological choice may be influenced by seemingly insignificant events that give one technology an advantage over another. First mover advantages may matter: a standard that gains an early lead in the technological evolution may develop a lasting advantage by locking out other technologies. This is reinforced by network effects. In the face of constant and diminishing returns to scale the evolution of the market reflects ex-ante endowments, preferences and transformation possibilities. Small events cannot influence the outcome. However, due to network effects there are increasing returns to scale that allow for multiple outcomes. Minor circumstances are magnified by positive feedback to "tip" the system into an outcome (*Arthur,* 1989).

With the existence of economies of scale in the innovation process and higher ex-post rents due to little competition, companies are in ex-ante competition for ex-post market shares. Competition between standards is fierce, and in industries with economies of scale pricing strategies tend to favour incumbency, and may eventually lead to monopoly structures, in which entry can be impossible. Even if the co-existence of different standards is feasible since a critical mass has been reached (e.g., *Economides – Himmelberg,* 1995), it may not be economically efficient. For instance, IBM developed an operating system for server terminals, the AS400, solely for its own standard. It was not compatible with any other system on the market at that time. Such separate standards tend to have artificially high prices due to a lack of competition, a situation that is often generated by firms that opt for incompatibility. This reduces competition between networks, and may be more profitable than competition under compatibility. Such a structure favours incumbents and might produce suboptimal outcomes from a social welfare perspective (*Farrell – Klemperer,* 2007).

If there is competition between standards, firms contest ex-ante for ex-post market shares; monopolies are possible. Then again, if separate standards are economically feasible, they may be inefficient, because they generate artificially high prices due to a lack of competition within a given standard.

A firm has to consider two counteracting effects in their decision whether to join a standard. On the one hand, greater market size allows firms to spread their sunk and fixed costs over a greater network. The expectations about the network effects and the likelihood of reaching a critical mass, and the equilibrium point positively affect the decision to join a standard (e.g., *Economides – Skrzypacz,* 2003). Given economies of scale, the pay-offs that adopting companies receive depend on their industry power (*Farrell – Saloner,* 1985). Moreover, risks around demand are reduced, and complementary goods are more likely to be available if technologies are based on a larger standard. On the other hand, standards lower entry barriers, thus promoting competition in product markets by favouring entry. Standards tend to make products more homogeneous, hence increase competition. Similarly, a larger sales platform implies more competitors (*Klemperer,* 2006).

Firms consider two counteracting effects when deciding whether to join a standard. Economies of scale and network effects attract them to a standard, whereas more competition within a standard has a repelling effect.

Official standards and technological uncertainty

In order to preclude market failures and welfare losses that standards may produce, policy makers have the option of officially certifying a standard. This renders standardisation an instrument of both industrial and innovation policy. An official standard is a document that was established by consensus and approved by a recognised national or international body. The presence of a consensus is a central condition that seeks to minimise potential costs. Alternatively, an all-knowing central planner would have to take the standardisation decision. More often than not it remains unclear whether a standard is the optimal choice. Policy makers typically cannot know the extent of network effects, technology channels, and how producers' and consumers' wealth are related (there might also be a trade-off between long and short-run effects between these two).

In the EU there are three recognised standardisation bodies, the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). These also collaborate with international agencies, such as the International Organization for Standardization (ISO) or the International Electrotechnical Commission (IEC). These authorities provide technical specifications, rules and guidelines. Official standards aim to achieve the optimum degree of order in a given context, and thus seek to be based on the consolidated results of science, technology and experience in order to promote optimal benefits.

Despite the consensus and the social welfare orientation of standardisation bodies, standards affect technology channels. In particular in an environment with multiple technologies, the choice of setting a standard is subject to fundamental uncertainty. Policy makers are confronted with erratic and unpredictable developments, which lead to two types of risk, both based on the lock-in of consumers due to switching costs: either a standard is adopted prematurely, or a standard fails to adopt to a superior technology due to the prevalence of established technologies (e.g., *Shy,* 2001).

Policy makers are confronted with erratic and often unpredictable technological developments. Even though the official setting of standards is consensus based, it comes at the risk of the premature adoption of a standard, or of excess inertia.

First, excess momentum refers to the premature adoption of a new technology over an existing, superior technology. Excess momentum occurs as a result of a "bandwagon effect", which describes a situation in which the network size has reached its critical mass, and firms imitate the technology because of the positive network effect. However, although network effects increase short-run pay offs, long-run returns are lower because the new technology is inferior to the old technology. In practise, excess momentum may be inflicted by non-technology neutral regulations, and is thus a central problem for standards in new technologies. Once a standard has been established, the situation might tip in the opposite direction – excess inertia, which describes a situation in which old standards are preserved despite the existence of superior technologies. Excess inertia is a common phenomenon in capital intensive industries, because obsolescence costs of a change in the vintage capital render technological change in production equipment expensive.

The bandwagon effect does not set in if the network size does not grow due to incomplete information, which is likely if there is sufficient uncertainty. This may even occur if consumers are unanimous in their technological choice. In such a situation, first movers are able to unlock the standstill and to start the growth process (*Farrell – Saloner,* 1985). One oft cited example of excess inertia is the prevalence of the allegedly inferior VHS (by JVC) over the technically superior counter-technologies Video 2000 (Philips) or Betamax (Sony). However, VHS was low-priced and open to specific film contents. Furthermore, engineering experts were more aware of the technical differences than consumers (e.g., *David,* 1985).

The pace of technological development

Since standards aim at promoting technological progress by acting as an innovation platform, they should be set at an early stage, when the sunk costs from other standards are low. This raises the question of the optimal timing for their adoption. Early implementation could lead to excess momentum by locking out infant technologies that might turn out to be superior in the long run. Yet, late adoption could deprive consumers and producers from network effects (excess inertia), and increase the risk of rendering duplicated development efforts in other networks futile. The likelihood for both depends on the innovation frequency, which alters across idiosyncratic sectoral characteristics such as the actual agents or networks involved, the knowledge base or shared technology institutions and demand conditions. In industries with an established knowledge base and growth predominantly taking place in incumbent firms, incremental innovation is the typical form of technological advance. Other sectors with younger firms and less sunk costs exhibit more radical types of innovation that is now typically driven by new firms (*Malerba,* 2004, *Utterback,* 1994).

Official standards in younger technologies are particularly prone to mistakes due to more uncertainty, whilst at the same time also harbouring greater potential. By contrast, standards may strengthen mature technologies and slow down technological progress, even though the artificial creation of a standard war contradicts the very rationale for public intervention.

The right timing is critical for the success of a standard. In mature markets, standards are typically set. Yet, the consensus orientation of standards generates the risk that technological progress will be slowed down because existing structures are merely strengthened. This brings with it the risk of distorting the technological evolution through excess inertia. On the other hand, when technologies are young and the vintage capital stock is negligible, standards are more prone to excess momentum due to technological uncertainty. Yet, if they create a technological platform, standards may lead to an increased rate of innovation due to new technological combinations becoming feasible.

Policy makers already have infant technology programmes in place that should counteract incompatibility decisions being made at the very early stages. For instance *Cowan* (1992) proposes increasing network effects from the very start by creating an inter-agency market. This market would explore the future returns of costly infant technologies and encourage early innovators to initiate the growth, or bandwagon processes. He claims that, other than intellectual property rights that are effectively ex-post, an inter-agency market lowers the risk in the early stages. Technologies need to be mature enough to enable a reasonable evaluation to be made. In addition, he is a proponent of the public funding of infant technologies. However, governments need to be aware of asymmetric information and unobservable factors, which may not exist at the time of evaluation.

Size neutrality and linkages

Network size positively correlates with the age of a technology, and is a critical aspect. Networks should represent a standard as broadly as possible, and include companies that increase the network size both horizontally and vertically (*Foray,* 1995). *Economides* (1996) looks at the sunk costs such as R&D and advertising, and expects the benefits of standardisation to be greater in sectors where the unification of certain properties brings benefits to both users and suppliers. In order to spread these benefits over a bigger client base, standards should be accepted by as many agents as possible, which would also ex-ante minimise uncertainty from parallel technologies.

An official standard should consider upstream and downstream linkages and complementary products and services to maximise the network size.

Hence, a company that promotes a standard will strive to create the network size required to reach the critical mass point. Such network externalities for instance played a decisive role in Ericsson's growth to a dominant position in the open data communication network architecture market. In order to increase the network size, the company allowed its proprietary system integration language software "Erlang" to be open source, thus also incorporating other firms' customer base. This decision was stimulated not only by network economic rationales, but also by the turnover of key R&D personnel some of whom started up their own firms (*Glimstedt,* 2001). Similarly, in order to establish a bigger network for WAP and Bluetooth, two mobile phone applications, Ericsson fostered the creation of a downstream market by promoting knowledge spillovers through the establishment of a corporate venture capital programme that was also open to Ericsson's employees, who were allowed to return to the company if they failed as entrepreneurs (*Casper – Soskice,* 2004).

SMEs of upstream and downstream markets benefit in particular from internalising economies of scale from the standard. They tend not to initiate standards, even though platforms and networks do exist. SMEs benefit from them due to lower interconnection barriers, but they are also prone to fiercer competition from large firms. Large firms may try to increase entry barriers to avoid competition from small firms.

Once firms have joined a standard, they typically specialise and cover niche markets. Downstream firms that use standardised inputs can choose from competing suppliers, which leads to amplified (combinatorial) innovation and price competition. Hence, firms can internalise parts of the economies of scale that the entire upstream industry exhibits. Standards create a level playing field regarding economies of scale at the input level (*Shapiro – Varian,* 1999B). Simultaneously, upstream firms are able to exploit increased economies of scale due to a broader customer base for compatible products.

Due to the sunk costs that are involved small and medium sized enterprises (SMEs) typically do not propose standards, even if some may develop technologies that are key to standards. Yet, some firms seek horizontal co-operation in research and development in the early stages, establish a standard, and then compete at later stages (*Cellini – Lambertini,* 2009). This could be described as "co-opetition", which is actively promoted by some policy makers through platforms. In ICT for instance, the International Telecommunication Union provides a size neutral standardisation platform which is both open and used by SMEs.

More generally, smaller firms tend to benefit from standardisation, because standards remove barriers to connect, which leads to a bigger operating platform that firms would not have had access to without the standard. On the other hand, SMEs are also affected by competition from firms within a standard. SMEs face obstacles when they seek to join a standard. Due to their smaller networks they are faced with a weaker bargaining power than large firms (also incompatibility is not economically feasible). Large companies that have already adopted a standard are aware of these difficulties, and may exert their market power by increasing their switching costs in the aim to exclude competitors from their market (*Shapiro – Varian,* 1999B). For instance, in the first decade of the 20th century, most automotive firms used common standards to reduce demand side risks. Smaller companies standardised their products, anticipating the benefits from economies of scale. However, the two main players at that time, Ford Motor Company and General Motors, refused to co-operate. Both internalised supply structures and gained from economies of scale, which was more profitable than a modular organisation of supply chains. Put differently, the profits from a market that a single supplier dominated due to a lock-in were greater than the extra utility of additional network effects that other suppliers could have brought (*Shapiro – Varian,* 1999A).

Standards require complementary technologies to be successful, and require a "network" of private firms identifying market opportunities and optimising resource allocation. Governmental intervention beyond standardisation tends to distort competition and cannot replace the emergence of complementary networks. A recent example of a "stand-alone" standard was TD-SCDMA, a Chinese mobile phone standard which was approved by the International Telecommunications Union (ITU) in 1999. Its development was regarded as a key project of the Chinese government that also co-funded research and development. The standard was jointly developed by research institutes, an American-Chinese firm, and foreign investors (*Liu,* 2006). Commercialisation began nine years after registration, and was very slow, because applications beyond sending and receiving calls were not supported by the handsets. The market was distorted by the government, since political interference through subsidies for certain developers of handsets hampered intra-standard competition. The result was that a critical mass was never reached (*Suttmeier – Yao – Tan,* 2006).

Governmental intervention beyond standardisation tends to distort competition, and cannot replace the emergence of complementary networks.

Switching costs and consumers' welfare

Consumers benefit from standards in a number of ways. First, they pay lower prices due to competition within the network and economies of scale and scope on the side of producers. Second, they gain from direct network effects, such as a greater product variety within the network, or from an increased possibility to "interconnect". Third, they can make use of indirect network effects, such as a larger maintenance network or a bigger secondary market (e.g., *Shy,* 2001).

However, if consumers prefer a technology that is not part of the standard, they might face difficulties changing due to switching costs. These stem from loyalty, a smaller network and thus a lower ability to interconnect, the costs associated with searching for more appropriate technologies, increased training costs or contracts that are designed to lock customers in. Yet, the network effects engendered by standards create switching costs and consequently lock consumers in. Firms may try to take these into consideration, and lock consumers in to skim off extra profits. Switching costs are also considered by a firm when deciding whether to join a standard (*Klemperer,* 2006).

Hence, the outcome of the decision whether to join a network is determined at an early stage. Once taken, the lock-in hinders customers from changing suppliers in response to changes in their efficiency. It gives firms lucrative ex-post market power, and power over the buyer who is faced with switching costs, and indeed power over other market players with network effects (*Farrell – Klemperer,* 2007). This may easily turn into a situation where firms abuse their market power, and competition policies become relevant. For instance, the biotechnology firm Qiagen has attempted to lock in clients for its disposable test kits by acquiring downstream, automated, computer assisted screening technology and then altering its product line in a way that they are only compatible with the firm's own test kits (*Casper – Soskice,* 2004).

Switching costs keep consumers from changing to another supplier. Firms may try to generate a lock-in situation to maximise profits, which may actually be contrary to competition laws.

A case study: GSM

The biggest success of an official standard is the second generation in mobile phone technology, GSM. According to the GSM Association, one interest group, the subscriber base passed 10 million in 1995; in 2003 there were already more than a billion subscribers, and in 2010 more than 5 billion used technologies that were defined in the GSM standard, serving approximately 80 percent of the global mobile telephone market across 212 countries. GSM was not only a success in Europe where it originated, but also created a global technological advantage for a European network of technology intensive firms (*Haug,* 2004).

The first coalition that started to develop a common digital mobile telephony technology had already been founded in 1982 – the "Groupe Spécial Mobile" (GSM). This group was formed by CEPT (the European Conference of Postal and Telecommunications Administrations), which was an organisation of 26 western European telecommunication administrations. In 1987, when a number of operators signed an agreement to launch GSM on 1 July 1991, the meaning of the acronym was changed to "Global Systems for Mobile Communications". In the same year ETSI, a standardisation authority of the European Union, took on responsibility for telecommunication standards. A year later the first commercial services operation was launched. Together with other standardisation bodies, as well as the 3GPP (Third Generation Partnership Project), ETSI defined GSM as a common standard, which was soon used by all major European operators. GSM served as an umbrella standardising the various systems which had used different frequencies prior to the standard. Thus roaming was made possible, which increased the size of the initial market to the whole of Europe.

The success of GSM is based on several interlinked factors:

- First, standardisation occurred in the very early stages of development. Other technical solutions that existed at the time were included in the standard, so that sunk costs were not lost. Later solutions that emerged outside Europe could not compete with the network effects. Effective competition between standards did not occur.
- Second, the group incorporated firms along the entire value chain, ranging from handset producers to network operators. Almost all major players that were relevant to Europe's mobile telephony sector at the time were involved. Despite the substantial size of the coalition, there was no voting mechanism necessary in order to take decisions, reflecting the level of the consensus based nature of the standard.
- Third, once subscriber growth started, network effects further intensified growth figures, and the impetus to innovate came less from laboratories, but increasingly from the demand side.
- Fourth, agreements between operators and handset producers broadened the pool of innovators, which, for instance led to the launch of SIM cards. Many innovations followed, such as text messaging (SMS), multimedia messages (MMS), GPRS (General Packet Radio Service) or EDGE (Enhanced Data Rates for GSM Evolution), or even later generations of the standard itself, 3G or 4G. The standard served as a platform from which a multitude of SMEs could benefit.

The industry growth rendered the sector a driver of European growth. It is unlikely that without the standardisation commitment of the EU, any producer would have invested the necessary amounts into research and development that were required to establish a comparable standard. Importantly the standardisation authority did not initiate the innovation and growth process but merely fostered the technological development by providing a framework and by setting the incentive structures.

Conclusions

Policy documents often mention official standards as an instrument to foster innovation and growth. Yet, the interactions of standards with firm behaviour and overall wealth are highly ambivalent. On the one hand, the underlying mechanisms of standards create positive network effects. Consumers benefit from greater operability through a larger network and a bigger secondary market, more product diversity, and lower prices due to competition within a standard. Producers benefit from industry wide economies of scale and scope that they can internalise, and are exposed to less risk due to switching costs and reinforcing network effects. Then again, standards come at the risk of creating social costs due to the inefficient duplication of sunk costs such as research and development, or advertisement expenditure which firms incur in their efforts to establish a competing standard. This is sometimes labelled as a "standard war". Official standardisation tries to prevent such standard wars and the related potential loss of sunk costs. Incompatibility, however, i.e., the use of an own standard, may be a firm's strategy if the profits of "locking in" consumers through switching costs outweigh the cost of more competition within the other standard (despite larger networks).

The need for standards tends to emerge automatically from industry demand. The use of standards as a strategic instrument is problematic, because policy makers set a technology path, even though they are uncertain about future technological developments. They might make mistakes when policies serve to keep suboptimal old technologies in operation (excess inertia), or suboptimal new technologies are implemented prematurely (excess momentum). Bearing in mind the risk of the wrong choice of technology, standardisation policies should consider the following set of criteria: First, standards should be implemented at an early stage in the life cycle of a given technology when no competing technologies yet exist, but after the initial trial and search phase. An overabundance of technological opportunities increases the risk of excess momentum. Second, a large base of firms is required to promote a standard, which should comprise of both horizontal and vertical linkages. Third, consumer preferences – often reflected by an existing critical mass – have to be considered. Fourth, standards should be firm size neutral, since SMEs tend to benefit more than larger companies from economies of scale and scope in an industry.

References

Arthur, W.B., "Competing technologies, increasing returns and lock-in by historical events", Economic Journal, 1989, 99.

Blind, K., Gauch, S., "Trends in ICT standards: The relationship between European standardisation bodies and standards consortia", Telecommunications Policy, 2008, 32, pp. 503-513.

Casper, S., Soskice, D., "Sectoral systems of innovation and varieties of capitalism: explaining the development of high-technology entrepreneurship in Europe", in Malerba, F. (Ed.), Sectoral Systems of Innovation – Concepts, Issues and Analsyses of Six Major Sectors in Europe, Cambridge University Press, 2004, pp. 348-387.

Cellini, R., Lambertini, L., "Dynamic R&D with Spillovers: Competition vs Cooperation", Journal of Economic Dynamics and Control, 2009, (568).

Cowan, R., "High technology and the economics of standardisation", in Dierkes, M., Hoffmann, U. (Eds.), New technology at the outset: social forces in the shaping of technological innovations, Campus Frankfurt am Main, 1992, pp. 297-300.

David, P., "Clio and the Economics of QWERTY", American Economic Review, 1985, 75, pp. 332-337.

Ebersberger, B., Pyka, A., "Innovation and Sectoral Employment – A Trade-Off between Compensation Mechanisms", Labour, 2002, 16(4).

Economides, N., Compatibility and Market Structure, New York University, Stern School of Business, 1991, http://www.stern.nyu.edu/networks/91-16.pdf.

Economides, N., "The Economics of Networks", International Journal of Industrial Organization, 1996, 14, http://www.stern.nyu.edu/networks/94-24.pdf.

Economides, N., Himmelberg, C., "Critical Mass and Network Evolution in Telecommunications", in Brock, G. (Ed.), Toward a Competitive Telecommunications Industry: Selected Papers from the 1994 Telecommunications Policy Research Conference, Lawrence Erlbaum Associates Inc., Mahwah, NJ,1995.

Economides, N., Skrzypacz, A., Standards Coalitions Formations and Market Structure in Network Industries, New York University, Stern School of Business, 2003, http://www.stern.nyu.edu/networks/Standards.pdf.

Farrell, J., Klemperer, P., "Coordination and Lock-In: Competition with Switching Costs and Network Effects", in University of California, Handbook of Industrial Organization, Elsevier North-Holland–Amsterdam, Chapter 31, Volume 3, 2007, pp. 1967-2072.

Farrell, J., Saloner, G., "Standardisation, compatibility, and innovation", Rand Journal of Economics, 1985, 16(1).

Foray, D., "Coalitions and Committees: How Users Get Involved in Information Technology (IT) Standardization", in Hawkins, R., Mansell, R., Skea, J. (Eds.), Standards, Innovation and Competitiveness: The Politics and Economics of Standards in Natural and Technical Environments, Brookfield, Aldershot, 1995.

Glimstedt, H., "Competitive dynamics of technological standardization: the case of third-generation cellular communications", Industry and Innovation, 2001, 8, pp. 49-78.

Haug, T., "How it all began", Teletronikk, 2004, (3), pp. 155-158.

Katz, M., Shapiro, C., "Network Externalities, Competition and Compatibility", American Economic Review, 1985, 75(3).

Klemperer, P., "Network effects and switching costs: two short essays for the new Palgrave", Nuffield College Economics Working Papers, 2006.

Liu, X., Path-following or Leapfrogging in Catching-up: the Case of Chinese Telecommunication Equipment Industry, Paper presented at CIRCLE Seminar Series, Lund, 2006, http://circle-lund.net/UploadedPublications/200701_Liu.pdf.

Malerba, F., "Sectoral systems of innovation: basic concepts", in Malerba, F. (Ed.), Sectoral Systems of Innovation – Concepts, Issues and Analsyses of Six Major Sectors in Europe, Cambridge University Press, 2004.

Schumpeter, J.A., "The analysis of economic change", in Clemence, R.V. (Ed.), Essays on Entrepreneurs, Innovations, Business Cycles and the Evolution of Capitalism, Transaction Publishers, New Brunswick, 1935, 17(4), pp. 134-149.

Shapiro, C., Varian, H. (1999A), Intro for managing in a modular age, University of Berkeley, School of Information, 1999, http://www.sims.berkeley. edu/~hal/Papers/modular.pdf.

Shapiro, C., Varian, H. (1999B), "The Art of Standards Wars", California Management Review, 1999, 41(2).

Shy, O., The Economics of Network Industries, Cambridge University Press, 2001.

Suttmeier, R.P., Yao, X., Tan, A.Z., Standards of Power? Technology, Institutions, and Politics in the Development of China's National Standards Strategy, The National Bureau of Asian Research, Seattle, WA, 2006.

Sutton, J., "Sunk Costs and Market Structure – Price Competition, Advertising, and the Evolution of Concentration", Massachusetts Institute of Technology, 1991.

Utterback, J., Mastering the Dynamics of Innovation, Harvard Business School Press, Boston, 1994.

Varian, H.R., Innovations, Components and Complements, Mattioli Lectures on the economics of information technology, Milan, 2003, http://www.almaden.ibm.com/coevolution/pdf/varian_paper.pdf.

von Hippel, E., The Sources of Innovation, Oxford University Press, Oxford, 1988.