RAISING STANDARDS: INNOVATION AND THE EMERGING GLOBAL STANDARDIZATION ENVIRONMENT FOR ICTS

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The purpose of this paper is to investigate the relationship between technical standardization and innovation in the ICT-sector. In many ways, this exercise involves revisiting the themes or sub-themes of much work already done in this growing area. In others, it involves linking the dominantly economics standards-oriented literature with systems–oriented innovation-studies and other cross-disciplinary approaches. Our objective here is to review some of this literature and, hopefully, provide a synthesis that advances our appreciation of standardization's role in the innovation process. This is an important exercise as a sure-footed understanding of the fundamental relationship allows one to appreciate the effects and implications of the standardization process within the changing environment, especially, implications for user-participation.

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In 1928, an early student of industrial standardization observed that, "Until international trade is conducted on a basis less strongly flavored with nationalism, and industrial education has made more progress than it has yet, there will apparently be little economic justification for extensive standardization." (Condit, 1928: 40)[1] There is little doubt that, 70 years on, a period of such extensive standardization is at hand in the information and communication technology (ICT) field. Indeed a new standardization environment is emerging, characterized by a proliferation in type and number of voluntary standards organizations and in new modes of working and inter-working within and between them. (cf. Werle, 2000) We recognize some of the reasons for this development: these include the liberalization of certain (telecom) markets, the rapid technological change of information, communication and broadcasting/media technologies and not least the ways these technologies converge. Although we recognize these factors and ingredients and we know in some detail the developments both in the procedures and the institutional setting, we cannot claim to know the medium to long-term effects of this emerging standardization environment. A particular area of concern is how the changing environment will involve a greater exclusion or inclusion of relevant interests in the process. Such concerns raise the need to evaluate the fundamentals of the standards-process.

In this paper, we will review some aspects of the changing standardization environment before considering the standardization process' economic justification. Then we will look at its role in the innovation process and finally we will consider some of the implications of the changing environment.

1. Standards and standard-setting processes

The questions 'what are ICT standards'[2], 'what is the standards-process', and, even, 'who is a user' (cf. Naemura, 1995 and Salter, 1995) of an ICT standard are not trivial questions with unambiguous answers. One problem lies in the difficulty of defining a phenomenon that is changing. In this case, there have been manifold shifts involving not only what, where, how, when (i.e. in the technology's life), and by whom formal standards are produced. Another

[1] Cited in OTA, Building Blocks of the Future, 1992: 11.
[2] "Is there some general taxonomic principle which economists might use in distinguishing among the many varieties of 'standards'?" (David,1987)

difficulty lies in the variegated nature of standards in this changing ICT field. A third lies, not least in the contextual diversity of those who attempt to analyze it.

It is worth beginning with a standard view of standardization as a baseboard for further discussion. There are different ways to classify standards and the standards process. The Office of Technology Assessment (1992) differentiated the concept of standardization in terms of what they standardize. According to these criteria, there are three main kinds of standards:

1. product standards
2. control standards
3. process standards

A second criterion involves how they standardize. Again, there are three kinds:

1. standards set through the market, on a de facto basis
2. standards set by government, through the regulatory process
3. and standards negotiated through a voluntary consensus process.

Here, we are chiefly interested in the last case, that is of standards jointly elaborated by diverse actors in voluntary standards development organizations (SDOs) like the ITU-T, the ISO/IEC, or ETSI.[3] Industry-standards as developed by consortia and other forums like ATM Forum, X/open or IETF are also increasingly relevant to the new standards-environment. We are especially interested in "baseline standards"[4] which promote compatibility between technologies at a "non-product" level.[5]

About the standards-setting process, a preface is also in order. An apt description of the phenomenon we are interested in is that:

> "Standards result from the intricate interaction of company business strategies, standards committee activities, government interventions, and processes of market diffusion, and they are rooted in the perceived technical requirements for developing, manufacturing, operating or using devices that are meant to inter-work with others." (Schmidt & Werle, 1998: 33)

In other words, standards-setting brings together commercial, academic and regulatory interests who, through complex interaction, identify the need for common specifications for a network-based technology and elaborate, develop and disseminate technical specifications. Why? What motivates and modulates this interaction and what is its relationship to innovation of information and communication technologies? Before we address such questions in sections 2 and 3, it might be helpful to make some general observations about the significance of standardization and its changing position.

During the past decades, formal standards-setting has played a central role in the development of information technologies and communication technologies. (Wallenstein, 1990) More recently, the production of technical standards has become an important precondition for the convergence of these previously separated technological areas. In addition to opening up new technological markets, standards are important in providing for growth in geographical markets. Technical standards are fundamental to cross-border compatibility and interoperability of information and communication technologies: in the environment of telecom re-regulation, these standards are directly associated with continued growth of world-trade and co-operation associated with 'globalization'.

2. Standardization and 'economic justification'

The economic justification Condit (see above) was looking for is but one of a complex set of factors in the perpetuation of today's globalizing standardization environment. It is however obviously central to the voluntary

[3] See Jakobs, 2000: 2.1. for a discussion of taxonomy.
[4] See Jakobs, 2000: 11. See also "coordinative standards" Schmidt & Werle (1998) and discussion below.
[5] See Tassey (2000) and discussion below

consensus standards and critical to our understanding of the role standardization plays as an institution in the innovation process. In this section, we will review some ways to understand the economic rationales for this institution. We will then consider some ways the literature has approached it, before analyzing more deeply the role it plays in the innovation process.

The static allocation perspective of the dominant (neo-classical) production theory is not directly helpful in understanding the economic rationale of formal standardization. In fundamental ways, standardization is indeed irrelevant to the theory. However, the ways in which it is **not** relevant to this theory is instructive to understanding its underlying rationale.

Neo-classical production theory focuses on how economic agents make allocation decisions in a state characterized by scarcity of resources, the absence of uncertainty and perfect competition of markets. In this somewhat tired view, rivals compete to supply established products at lower prices on saturated markets. Firms face a choice of what to produce and how to produce it. Calculations of rates of returns based on known factor prices inform the firm's decision on how to (re)allocate capital and labor inputs in order to maximize profits. In an efficient market, the firm can move at negligible costs from production function to production function in search of higher profits.

This view puts a premium on facilitating flexibility both at the firm and at the level of the economy as a whole. In the first instance, firm performance is predicated on its ability to adopt new production techniques and enter new markets with ease. In the second, the efficiency of the economy depends on promoting entry and exit without friction. The position of technology in the sense of new knowledge, the creation and acquisition of which would seem to be central to the ability to compete, is not made explicit is such a model. Technology is instead abstracted to the level of information. Information is expected to exist in publicly-shared stocks, more or less equally available to all agents at negligible cost. On it, individual agents make rationale decisions based on their individual preferences in perfect competition with other agents.

The archetypal state taught in this theory is obviously at variance with the observable state of ICT markets in several essential ways. In general, the theory is not very well endowed to deal with the uncertainty of innovation nor does it go very far in describing the situation that faces most agents in their markets. There are several particular discrepancies between the assumptions of the theory and the reality that are worth highlighting as some of the basic economic rationales for the formal standardization of information and communication technologies come into relief by doing so. In this context, we want to highlight three areas of discrepancy that are relevant to the way formal standardization works. These are the assumptions regarding (i.) price as the selection mechanism, (ii.) the relevance and nature of information and (iii.) the nature of goods and of agents.

i. Price competition and uncertainty

The theory assumes that economic agents compete on price and that it is price-competition that selects winners. In the ICT field, vendors typically do not compete primarily on price in more or less saturated markets characterized by perfect competition. The position of price is not of primary importance as a selection mechanism in this context. What ICT-vendors are faced with are globalizing hi-tech markets with shrinking product life-cycles and resilient levels of demand. In this setting, technology is more central to an economic agent's competitiveness. Instead of price competition, one has a situation that is more like Schumpeterian "technological competition."[6] (Schumpeter, 1942) The rate of technological change combined with increasing complexity (cf. below) and high cost-levels of R&D means that uncertainty is a major problem.

The development of collective standards is one way to reduce uncertainty in rapidly changing markets. The development of a new technology with standardized characteristics potentially opens up a market and possibly even adjoining or supplementary markets for the population that supports that standard. The short product cycles of ICTs contribute to a situation in which it is difficult for single agents to dominate the markets. This raises the incentive for a greater variety to converge on individual standards. Granted that the (product) standard is a success on the market, "competition among suppliers of the 'standardized' product then become increasingly based on price and service-related aspects of the product's acquisition and use." (Tassey, 2000: 592) In other words, the standard acts as sort of a "nonmarket selective environment" (Nelson & Winner, 1977) and gives the price-competition assumption of the theory an opportunity to work.

[6] In this setting, risk-taking agents compete through an expensive search process to commercialize new technologies on unsaturated markets with correspondingly high profit-margins. Selection occurs when risk-taking entrepreneurs introduce new technologies that compete both with incumbent technologies and with other new technologies. Here Schumpeter stresses the importance of monopoly rents to recoup R&D outlay.

ii. Perfect Information

The static allocation theory attempts to commodify the technological knowledge agents would need in order to produce and compete in different markets. The theory assumes a special ideal type of information but does not expand on its dimensions. This ideal type of information would have to be *generic* (widely applicable), *codified* (in a form that is easily transferable, for example in the form of a manual), *freely accessible* and *context-independent* in order for firms to even begin to make optimal profit maximizing choices. (Smith, 2000: 83) Clearly, the accumulation of technological knowledge is not of this order, not least in information and communication technologies. The knowledge one needs in order to be able to produce and compete in ICT markets is not a discrete entity of publicly-shared information which can be acquired instantaneously. It is of course a complicated, costly and timely learning process to develop the technological and attendant capabilities.

Standardization can be seen as an attempt to make certain elements of technological knowledge more like this ideal type of information. The standards process is designed to codify generic types of knowledge that underlie a technology and to make it available to a wide set vendors and users at negligible costs. A standard becomes something like the stock of publicly shared knowledge assumed by the production theory. This reduces information costs and reduces the collective risk associated with adopting new technology. Some claim that the economics of standards, at base, essentially a phenomenon that addresses the market's inability to deal efficiently with information such that, "the establishment of standards has greatest significance when economic agents cannot assimilate without substantial costs all the relevant information about the commodities that may be exchanged with other agents, and the processes by means of which those goods and services can be produced." (David , 1987: see also below)

Because a bona fide standard acts to diminish uncertainty, it lowers transaction costs for manufacturers and other actors, increases the efficiency of information flows to the user and improves productivity by diminishing inefficiency associated with protracted trial and error processes in manufacturing. (David, 1995) Thus, standards are a key element of the "selection environment" for network ICT, addressing the special challenges that 'technological competition' poses here. For economic agents, standards can produce a platform on which to move more easily into new product areas: in other words, it provides something of the flexibility assumed by the theory. For the economy, standards can avoid efficiency losses due to the market's inability to establish a standard (cf. David 1987: 208) and it can potentially facilitate the entry of a greater number of agents. The question of whether the standards process does this, or whether in fact it excludes outsiders from participating in markets is important.

iii. goods and economic agents

The static allocation perspective also assumes a stylized type of good. Products are discrete substitutable stand-alone units with known characteristics. Their markets are unaffected by those of other goods. Their production is static and unit-cost may actually increase the more units that are made. (i.e. there are constant or decreasing returns to scale) Many information and communications technologies differ substantially from this stylized type in several important ways. They tend to be complicated technologies involving many elements whose characteristics are not obvious. The soaring cost of developing new technologies testifies to this. Their value often depends on other products or compatible components in the sense that a minidisk complements a minidisk player, an operating system complements a computer etc. They may be subject to increasing returns to scale. (Arthur, 1989) And relatedly, the cost and value of products may depend on the number of others already using (installed base) and/or attached to the network. (network externalities)

The existence of 'network externalities' opens up one of the most noted rationales for formal standardization. (Katz and Shapiro, 1985) There are in general two types of such externalities or 'effects'[7]. In traditional communications networks, the value or a telephone increases exponentially with the number of other telephones with which it can communicate. In addition, there is the network effect based in 'virtual networks' where the value of the consumer's technology is affected by the installed base who share a common technical platform. In addition, many information technologies are affected by increasing returns to scale. These cases are typified by high initial costs (e.g. creating software) and low marginal costs (e.g. reproducing it on CDs).

Formal standardization addresses the need to promote compatibility among components and thus reduces the cost of developing and operating complex technological systems[8]. The central idea is that, "whenever goods or services are complementary, their production or consumption can have positive (or negative) externalities, implying individual

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[7] A term that does not necessarily imply the existence of 'market failure'.

[8] Note the 'two faces of compatibility'. Cf. (Werle, 2000)

actions affect the utility of other actors." (Schmidt & Werle, 1998: 74)[9] The assumption is that markets are themselves inefficient in standardizing network technologies. A central result is that, "Increasing compatibility leads to rising demand so long as the increased value of products offsets the cost of altering them." (Foray, 1995: 193) A second implication is that these network effects can serve to keep markets stuck in inferior technologies. The efficiency of the market as the ultimate selective mechanism stands the risk of being inefficiently slow. Alternately, there is the fear that the market becomes simply too reticent or indeed negligent in making choices such that, given a fragmented set of choices, the market does not converge on a single set of technologies.[10]

iv. Some further observations

The turbulence of many ICT-markets, the connectivity of these markets and prevailing uncertainty makes the idea of rational decisions of atomistic agents something of a tautology. The level of uncertainty and the need for types of coordination are not reduced by the fact that ICT implies a conversion of IT and communication technologies with content providers too. Relatedly, there is in this situation considerably greater orientation towards, and interaction with, the demand-side than that suggested by the production theory. Further, there is a notable degree of vertical and horizontal interaction on the supply-side of ICTs, which is partly explained by the levels of uncertainty and partly by the complexity of the goods in some sectors. It is therefore necessary to appreciate that human-factors are integral to the way ICT systems work and the way the behave on markets.

In general formal standardization in a greater share of the economics literature begins with the idea of the 'failure' of markets. Schmidt & Werle (1998) indicate that the focus tends either to be on the reduction of transaction-costs, especially related to information, or on associated with network externalities. Drawing on these authors and others, some of the main economic rationales can be summed up:

The economic dimensions of standards:

1. Encourage market entry and enhance competition by clearly defining what is required to serve a market (information)
2. 'Standards influence the distribution of cost and benefits of building and operating large complex technical systems' (Mansell, 1995: 217)
3. Facilitate scale-economies for suppliers
4. Allow increased and controlled variety for both users and suppliers
5. Reduce transaction costs
6. Standard as a public good (Berg, 1989)
7. Standards constitute markets by defining the relevant aspects of products. (Tirole, 1988)
8. Compatibility standards can increased value for each additional user.
9. "Trade-off between the efficiencies arising from variety with those arising from the positive externalities of the uniform technical standard" (Steinmueller, 1995: 184)
10. "Variety convey efficiencies in specialization and customization that are offset by the failure to achieve network externalities and other economies of scale." (Steinmueller, 1995: 185)

3. The standardization process and the innovation process

The economic justification—even if an enduring and adequate normative rationale—is necessary but not sufficient to a full understanding of the role formal standards-setting plays in the innovation process. Indeed, the socio-economic importance of standardization is much greater than market–failure. In short, "the received view about standards is flawed." (Williams, 1999: 258)

[9] With reference toTirole, 1988 and others.
[10] See David & Greenstein (1990) for a typography of failures in 'unsponsored standardization processes'.

More heterodox economic approaches, including institutional, organizational and evolutionary theories, may provide more insight into the standardization process. Given the "intricate interactions" involved in the standards process and its changing position, a cross-disciplinary approach seems appropriate and necessary. In this section, we will review some basic elements of an innovation-studies perspective while reviewing three relevant perspectives of the standards-setting process.

i. Systems-oriented innovation theory

The systems-oriented innovation literature[11] is in general well endowed to understand the nature of agents, institutions, knowledge and the dynamic interaction between them and thus the relevance of the standards process for the innovation process. The general case emphasizes the importance of complex interactions in the economy for the innovation process. [12] They highlight on the one hand the importance of interaction between economic agents, (cf. Freeman 1987; Lundvall 1988; Van de Ven & Garud, 1989) especially between users and producers but also involving interaction with other agents in a network. An understanding of such linkages is necessary in order to explain the relationships between economic agents in the ICT-area. On the other hand, the systems-oriented innovation literature stresses the interaction between the economic agent and its environment, especially the regulatory and institutional framework with which, and through which it interacts. One—perhaps increasingly— important element of the institutional framework in which ICT-firms live and breath is the constellation of standards development organizations.

The basic premise for much of the systems-approaches is that firms do not produce innovations in isolation; neither in isolation from each other nor from the influence of the institutional framework which helps define their environment (and which they help define). Firms are often reliant on complementary assets to innovate and often rely on outside sources for significant amounts of their innovation. A more neoclassical view would indicate that a firm is then faced by a make-or-buy decision contingent on the appropriability and other dimensions of the inputs. And indeed, an importance source of technological knowledge and impulse for innovation develops between the user and the producer. (for example a telephone network and a switch producers) However, even in this case the relationship involves collaboration in articulating and implementing the technology (cf. sticky or tacit nature of knowledge) and not just a once-off transaction. In terms of inter-firm linkages, "users are a decisive link in the chain of positive feedbacks: the learning by using mechanism which is at the root of the dynamic evolution in the technology of a standard," (Foray, 1995: 193)

As the discussion of network-externalities would suggest, this sort of collaboration is especially widespread in cases of network-technologies. In such cases, it may be in the best interest even between rivals to collaborate on the basic principles of a complex technology. Such situations raise the importance of institutions which help facilitate the interaction between firms and other involved parties from research institutes or governments. Locii for voluntary standards-setting is of course key. "The involvement of users, for example, is obviously very important for a number of reason—not least because users have a major role to play in the innovation process and the development of better technologies." (Lundvall, 1999: 9) Standards development organizations and industrial consortia can lay the basis for win-win results from collaboration, especially when compatibility is king and standardization in the generic technology can raise the possibility for customization in the specifics.

The 'social system framework' of Van de Ven (1993) is one basic approach that illustrates the importance of the interrelationship between the 'industrial or technological community' and the 'industrial infrastructure'. The industrial community includes both private firms who develop and/or use emerging technologies as well as other actors from the public and private sectors 'who play key roles in the development of an industrial infrastructure of innovation'. (Van de Ven, 1993: 339)

The Industrial infrastructure for innovation includes:

1. Institutional arrangements legitimate, regulate and **standardize** a new technology,
2. Public resource endowments of basic scientific knowledge, financing mechanisms and a pool of competent labor,

[11] E.g. the National Systems of Innovation Approach (Lundvall, 1992), the "social systems framework" (Van de Ven, 1993), knowledge systems (David & Foray, 1995) etc.

[12] See Smith (2000), Innovation as a Systemic Phenomenon: Rethinking the Role of Policy. Enterprise & Innovation Management Studies, Vol 1: 73-102.

3. As well as proprietary R&D, manufacturing, marketing, and distribution functions that are required to develop and commercialize an innovation. (Van de Ven, 1993: 339. Emphasis added)

On this basis, the argument is of a symbiotic and dynamic relationship between the industrial community and the infrastructure, not least standards development organizations. It posits that, first, the innovative-capabilities of firms in an industry is contingent on the level of development of the industrial infrastructure. And, second, that the infrastructure emerges and develops based on the combined effect of the 'actions of many public and private sector actors over an extended period of time.' It should be noted that, although the relationship is essentially dynamic and symbiotic, the infrastructure can become an "inertial force" that can constrain industrial development. (Van de Ven, 1993: 353) In other terms, this is the danger that the "institutional glue sets", turning standardization into a source of rigidity for technological change. (cf. Mansell, 1995) It is important the institutional environment should be able to adapt at that juncture.

This infrastructure, which economists commonly see as outside the system, can also be seen as "technological infrastructure."(Tassey, 1991) In this view, the function of standardization is in effect layered in with the resources available to a firm, in combination with other resources:

> "the technology infrastructure consists of science, engineering and technological knowledge available to private industry. Such knowledge can be embodied in human, institutional or facility forms. More specifically, technology infrastructure includes generic technologies, **infratechnologies**, technical information, and research and test facilities, as well as less technically explicit areas including....forums for joint industry-government planning and collaboration..." (Tassey, 1991: 347 emphasis added)

"Infratechnologies" include certain types of standards, especially compatibility standards. Tassey makes the link with standardization explicit (Tassey, 2000) where he differentiates standards according to two dimensions:

1. by their relationship to product (or service) structure
2. by their public-good content. (from totally proprietary to totally public)

The Tassey categorization is based on the effects the standard has. Primarily, a standard can directly involve a specific product or process, in which case it affects competitive position of its sponsors. Alternately, its effects can be "non-product" and thus not directly involve the competitive environment within the industry or trading-block for which it was developed. Non-product standards themselves become 'infratechnologies' such as measurement and test procedures and interface standards. These infratechnologies therefore become an integral part of the innovation process, between the firm and its environment.

An alternate approach construes standards purely in terms of 'information'. (cf. the perfect-information discussion above) rather than knowledge or a sort of technology. David (1987) distinguishes the nature of the things with which the standard is concerned (technical reference standard, minimum admissible attribute or technical design interface) from the 'informational function performed by the standard in reducing transaction costs.' As information, standards can specify a technical reference standard, minimum admissible attribute or technical design interface. They can facilitate communication within an industry,[13] they can reduce the cost of information acquisition for economic agents by reducing variety and they can yield uniformity which permit scale economies ('economies of repetition'). In network technologies, standards can be seen as promoting technical inter-relatedness between components and promoting economies of scale. David (1987)

This, however, is not a two-dimensional exercise. For the economy, it involves the (impossible?) situation of:

> Finding a 'best policy flux' , an optimized path and rate of movement across the mutable landscape bounded by freedom and order; between promoting forms of coordination that support creativity and the generation of variety in the early stages of a technology's development, and promoting coordination in selection and implementation when the technology has matured to the extent that its capabilities of

[13] See Link, 1983.

> satisfying the variegated needs of users are understood, while attending to the spillover or externalities that such actions may have for interrelated areas of technological development. (David, 1995: 35)

One recent approach has attempted to address the complexity from an integrated approach that address the social, political and economic issues involved in formal standardization. The *actor-centered institutionalist approach* of Schmidt & Werle (1998) implies that understanding the economic rationale (even if possible in every case) does not in itself entail understanding formal standardization, neither in its process nor its effects. Accordingly, this is a cross-disciplinary approach that tries to integrate elements from economics, political-science and sociology to study the complex phenomenon of standardization.

Like many of the approaches, Schmidt & Werle (1998) differentiate between three 'modes of standards setting', (i.e. by market, by firms, by regional and international committees and corsortia). Their focus is on the last and then on "coordinative"[14] standards. Their heuristic model of the standardization process features three blocks with case-by-case properties:

1. Structural aspects, involving the institutional framework, actors and technological foundation
2. Process aspects, involving the decision making process
3. Output, involving the approval dimension.

The use of the Social Construction of Technology (ScoT) framework (Bijker, Hughes &, Pinch, 1987; Bijker, 1995) is notable in this approach. Using it, Schmidt & Werle approach the standardization process in terms of an 'interaction of actor-related and institutional variables with case-specific technical factors'. On the first account, actors are—far from the economic agents of the neoclassical world— 'composite' agents characterized by 'soft rationality'. The actors involved in the standards writing process create a 'constellation' of heterogeneity of interests, perceptions and preferences which are not necessarily strictly in keeping to the economic agents (i.e. firms) they represent. The institutional rules of the individual standards development organizations (the rules seem to be surprisingly isomorphic across standards development organizations) (Werle, 2000) constrain and can direct the 'interpretative flexibility' of these actors.

In this setting, the role of standards is coordinative in the larger process of technical development: "what they coordinate is human action concerning the design, production, combination, maintenance or utilization of technical artifacts. Compliance with the rules promises compatibility and thus promises the artifacts' smooth interoperation in a system. The rules of course are addressed to actors and a selection of these actors sets the rules in standardization processes." (Schmidt & Werle, 1998: 109)

4. A new globalizing standardization environment

The observation that infrastructure emerges and develops based on the combined effect of the 'actions of many public and private sector actors over an extended period of time' and that infrastructure can become an "inertial force" that can constrain technological development (Van de Ven, 1993: 353) is an apt place to return to our point of departure: i.e. that there is emerging a new standardization environment.

Formal standardization is clearly a phenomenon in change, and has been for about a decade. There are several factors of this change and several more or less obvious manifestations. In terms of factors, we can return to Condit (1928) and the observation of the enabling role of international trade. Trade-liberalization, both national and international, is undoubtedly a central explanation for the growth of the forest of standards development organizations and undergrowth of consortia etc. On the one hand, the liberalization of telecom markets beginning in the 80s and continuing to this day, paves the way for the emergence of new SDOs and not least new types of standards. The replacement/upgrading of CEPT by ETSI in Europe in 1987/88 was an immediate result of such a process. Its birth was accompanied by the birth/growth of other regional SDOs in Japan and North America. As Werle (2000) indicates, this regional diversification reflected the "competitive concerns of regional companies" in a liberalizing market. In addition, the changing position of countries like China or of those of Eastern Europe affects the changing environment.

[14] As opposed to 'regulative'. See also Gaillard (1934).

One set of manifestations is that the, "the complexity of modern technology, especially its system character, has led to an increase in the number and variety of standards that affect a single industry or market." (Tassey, 2000: 587) There are new methods of standardization, 'meta-standards' (Steinmueller, 1994), incomplete, anticipatory and gateway standards. In the current environment, "standardization attempts to anticipate market trends with a view to developing a product and working of prototypes which entails activities evermore closely linked to research and development." (Foray, 1995: 211)

In the ICT-field the proliferation of the number and variety of standards is further mirrored in the institutional environment. Further, "the role of standards is changing because of the increasingly 'configurational' characteristics of contemporary ICT-systems, which opens up new choices about the internal composition of a complex ICT application." (Williams, 1999: 258) This is a deeper set of changes which can open greater choice but—perhaps also—greater control.

There is an increase in number and variety of standards development organizations and other formal standardization organizations. And thus there is an increasing potential for linkages and collisions. The growing demand for standards and standardization means, inter alia, that, "the intersection and overlapping of technical competences in turn has created struggles among different voluntary standards organizations in the 'market' for published standards. "(David, 1995: 30) There is indeed a challenge to coordinate the growing diversity of what are, in many ways, coordination-mechanisms. However Werle (2000) indicates that there are processes of coordination at work in the "landscape of standardization organizations," in addition to competition. Standards development organizations have indeed tried to address this potential for conflict, partially brought on or at least exacerbated by technological convergence, creating liaisons. Moreover, new types of cooperative institutes like the Joint Technology Committee (JTC1) or the Joint Committee on Information Infrastructure Standards. On the axis between standards development organizations and industry consortia standards there is likewise less talk of a collision course than there was 5-10 years ago. Here, there are some indications of a movement towards, "hybrid selection processes, where both market competition and negotiation play a role." (Vercoulen & van Wegberg, 1999: 1)

External to the standards development organizations, but internal to the standardization environment (at least as far as governments are concerned) are challenges that involve balancing standardization with other regulatory and trade measures. Again the risk is that standardization, as an 'institutional glue' ceases to, "reflect the need to coordinate knowledge accumulation and the flow of information..." and may simply "reinforce technical designs and implementation choices in ways that reflect the history of past investment decisions rather than future opportunities associated with innovation." (Mansell, 1995: 214-5)

The emerging global framework draws into question the ability of small and medium-sized enterprises and other actors to effectively participate in standardization. Above we mentioned the importance of the linkages between user and producer and indicated the importance of 'learning by doing' effects also in the standards-setting process. In terms of web-based technologies, developments, for example in the IETF, (Jacobs, 2000: chap 6) have with some success been able to derive efficiencies in the standards process from much more open participation than traditional SDOs. In part this is because of the technology.[15] Notwithstanding, it indicates the possibility and the desirability of securing a non-exclusive set of interests in the increasingly global and increasingly expensive enterprise of standardization.

Conclusions

On this important note, let us round off by again stepping back 70 years when Gaillard (1934) identified the purpose of 'industrial standardization' as being essentially two-fold. According to him it establishes, "**temporary constant level of requirements** or conditions under which the practical industrial application of **a basic idea** will be possible, **technically** as well as economically; and it coordinates factors, "whose harmonious working together is required for complying with the conditions determined by that temporary level of stability." (Gaillard, 1934: 14 emphasis added) He argued further that, "in combining the two functions care must be taken to leave sufficient **facility for making a shift from one temporary level** to the next one, if and when this becomes necessary due to progress made in the art. " (ibid.)

This dual-purpose— and, moreover, the need to shift between temporary states— goes not only for the technical standardization within the standards development organizations but also for the institution of standardization as a whole. In the first sense, Gaillard introduced one of the central tensions in the standardization process: the delicate

[15] i.e. software as language, which is very much dependent on the user. cf Foray, 1995.

balance between establishing and shifting temporary re-configurations not only of technical and economical factors but others that are prerequisite to achieving temporary stability. The need for temporary conditions of technical and market stability and the need for coordination of system-factors are two functions that are increasingly recognized as essential conditions of innovation in information and communications technologies. Moreover, it is important to make a shift between temporary states in order to secure progress. Consider for example the case of shifting from second generation to third generation (3G) mobile systems.

This same analysis could be applied to standardization and the formal standardization environment. A temporary level of conditions has been important for this institution to fulfill its complex purpose. As an institution, the configuration of standards development organizations has supplied the basis for (mostly) harmonious collaboration of central interests. Things are changing at different levels. It has therefore become important that the ICT Standardization as a whole, itself makes a shift to the next temporary level. There is every sign that such a shift is underway. The question is whether its role in innovation will be maintained, especially with regard to the question of inclusive participation.

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