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A resource interaction perspective on standards competition: Some evidence from the optical recording media industry

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Abstract

This paper aims at developing a deep understanding of standards competition using a perspective of resource interaction and uncovering how a firm, in the face of such competition, is able to maintain its competitive position. A qualitative and case-based approach that comprises a processual analysis is considered appropriate to investigate the interactive nature of technological development, including competing standards. To facilitate the investigation of research problems, a technology-bundled net is adopted to delimit the boundary of this network research.

With 72 interviews and archival materials, a process of resource interaction characterised by inter-standard competition and inter-generation competition in the optical recording media industry is presented, covering a time period from 1998 to 2008. The findings permit the development of new insights around “the compatibility in resource interaction”. The findings also allows us to propose “positional flexibility” as an important means for firm being embedded in technology-based network to dynamically respond to rapidly changing conditions, such as technological change.

Keywords

Standard; Technological Change; Innovation; Resources; Interaction

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Introduction

It has been demonstrated that innovations and standards alike result from networks in which the phenomena of business interaction prevail (Håkansson and Waluszewski, 2002; Lundgren, 1995; Lundvall, 1992; Metcalfe and Miles, 1994; Powell *et al.*, 1996). Networks are information-rich and self-adaptive structures that allow firms embedded in these structures to change the ways how aggregate resources are combined and used through interfirm relationships; and thus, advancing technological development (Achrol and Kotler, 1999; Ritter and Gemünden, 2003). That is to say, the emergence and success of a standard (e.g. VHS videocassette format) can be seen as the result of collective actions of interconnected actors in a technology-based network.

The emergence of standards does not take in a vacuum. In stead, a standard evolves in a process characterised by the interplay of stabilising and changing forces, in which the former focuses on the development of the standard along the established technological path while the latter emphasize the variety-generating feature of the evolution, including rival standards and the next generation of technology (Håkansson and Lundgren, 1997; Metcalfe and Miles, 1994). This evolutionary process is usually marked by standards competition which represents the rivalry between different patterns of the combination and usage of resources across firm boundaries. When viewing firms as bundles of resources, firms participating in a standards competition by using their resources in relation to others signify their efforts to enhance their competitiveness (Bettis and Hitt, 1995; Danneels, 2002; Penrose, 1995; Yamada and Kurokawa, 2005).

The knowledge about standards competition and the success (or failure) of a standard has been enhanced by a number of studies. Hill (1997), Metcalfe and Miles (1994) and Mohr *et al.* (2005) have indicated that product compatibility, such as the compatibility between hardware and software in the PC industry, is an important determinant of establishing a standard. Similarly, Moore (1991) argues that the key for a standard to be accepted by the mainstream market lies in constructing the whole product, which takes into account the product compatibility. The concept of compatibility emphasizes the importance of complementary resources in the promotion of technological innovation or standard, such as resources used in production and marketing activities (Cooper, 1979; Cusumano *et al.*, 1992; Håkansson and Waluszewski, 2002; John *et al.*, 1999; Yamada and Kurokawa, 2005). A classic example of this is the triumph of JVC's VHS format over Sony's Betamax format (Cusumano *et al.*, 1992).

With the expansion of complementary resources in terms of increasing numbers of applications, producers, marketers and users, an established standard is able to enlarge its installed base; which in turn, returns (e.g. economies of scale) increase, allowing a self-reinforcing mechanism to be created (Arthur, 1994; Besen and Farrell, 1994; Hill, 1997; Schilling, 2002). Such a positive feedback caused by the enlarged installed base signifies that the development of a technological standard is path-dependent (Arthur, 1994; Dosi, 1988; Håkansson and Lundgren, 1997). Furthermore, the positive feedback tends to lock-in the established standard and to lock-out other competing standards, even these standards have better technological designs than the established one (Schilling, 1998). This lock-in effect is best exemplified by the case of QWERTY keyboard (David, 1985).

The above evidence regarding standards competition is in accord with a perspective of heterogeneity. The success of a standard hinges on the interaction between resources possessed by different economic actors (e.g. suppliers, customers, competitors and complementors). It is also this interaction in a web of interconnected interfirm relationships that a firm's capabilities and competitiveness are defined (Araujo *et al.*, 2003; Ritter *et al.*, 2004); and thus, determining the firm's success of adoption a technological standard or innovation (Afuah, 2000). However, the interactive nature of standards competition in a network setting remains poorly understood. Especially, a firm's ability of handling resources across firm boundaries to develop technology is facilitated, and simultaneously, constrained by the network structure of which it is part (Håkansson and Ford, 2002; Uzzi, 1997). Thus, the purpose of this research is to 1) develop a deep understanding of standards competition in the process of business interaction and 2) to uncover how a firm, in the face of standards competition, is able to maintain its competitive position.

In order to address these two research questions, this research employs a perspective of resource interaction which is grounded in the IMP Group's interaction and network approach (Håkansson *et al.*, 2009; Håkansson and Waluszewski, 2002; Turnbull *et al.*, 1996). The resource interaction perspective serves as a proper theoretical basis to study technological development in a process of business interaction between material (e.g. product) and immaterial (e.g. organisational knowledge) resources across firm boundaries; and thus, facilitates the investigation of standards competition. Moreover, this research purposefully selects the optical recording media industry as the empirical setting because the rapid changes in technology over the past decade in the industry provide a suitable setting for the adoption of a

processual research design. The industry is also characterised by the co-existence of inter-standard, intra-standard and inter-generation competition (Besen and Farrell, 1994; Yamada and Kurokawa, 2005), which facilitates the investigation of the two research questions.

The paper continues as follows. In the first section, a theoretical framework that relates resource interaction to the development of technological standards in networks is provided. The next section rationalizes the employment of processual research in terms of its relevance and importance to the research problems. This section also includes an account of how empirical data is collected and analysed. Then, a longitudinal case that describes the evolution of resource interaction within a focal net is presented. Prior to the conclusions, theoretical and managerial implications are discussed.

A resource interaction perspective on technological development

The concept of resource interaction is grounded in the IMP Group's Interaction and Network approach (Turnbull *et al.*, 1996). Built on a heterogeneity perspective, a central notion of the IMP's approach is that business actors acquire complementary resources and engage in a chain of productive activities through developing interfirm relationships, so as to pursue economic goals and produce value (e.g. technological innovation) through collective actions (Håkansson and Ford, 2002; Håkansson *et al.*, 2009; Möller and Svahn, 2006). The consequence of firms developing interfirm relationships is that "markets" are replaced by "networks" which are characterised by connectedness and embeddedness (Anderson *et al.*, 1994; Mattsson, 1997; Uzzi, 1997). That is to say, in a network economy, the value of a firm's technological resources lies in how they interact with resources of other firms connected by interfirm relationships.

The concept of resource interaction was formally introduced in the work by Håkansson and Waluszewski (2002). Resource interaction (or the 4R model) distinguishes and emphasizes the interplay between four types of resources: 1) products, 2) production facilities, 3) organisational (or business) units and 4) organisational (or business) relationships. Products (seen as tangible resources) can be used, combined or moved around by different organisational units; and they can broadly include materials, components or end-products. Product facilities (also as tangible resources) has more permanent and stable features than products; and they are usually

controlled and used by certain organisational units to perform productive activities. Organisational units are viewed as pools of intangible resources, including the knowledge and experience of individuals and groups towards the handling and utilisation of tangible resources. Moreover, organisational relationships are seen as a type of resource entity because they can create different combinations between tangible and intangible resources across firm boundaries, allowing technological development to be advanced.

Resource interaction between tangible and intangible resource entities across firm boundaries is crucial to the establishment of a technological standard. Only through a process of interaction, technological resources of different firms can be systematically bundled in order to create complementary resources around a standard, including production and marketing know-how and skills and the compatibility between products and services (Cooper, 1979; Hill, 1997; John *et al.*, 1999; Metcalfe and Miles, 1994; Mohr *et al.*, 2005). Using an interactive view of bundles of technology (Ford and Saren, 2001), the prosperity of a technological standard must be built on its ability to attract and amass sufficient resources of different economic actors, which can be classified into “product technology” (the ability to design a product or component valued by others), “process technology” (the ability to manufacture a product) and “marketing technology” (the ability to market and deliver a product to those who need it). In other words, the bundles of technologies through relational linkages consequently result in the emergence of a technology-bundled net or system on which a technological standard rests (Håkansson and Lundgren, 1997; Henderson and Clark, 1990; Metcalfe and Miles, 1994; Möller and Rajala, 2007).

The bundled resources of a technological net or system do not guarantee that a technological standard will become a dominant design or prevail in the mainstream market (Moore, 1991; Suárez and Utterback, 1995). Instead, the success of a technological standard hinges on how bundled resources interact to create fits between established resource interfaces, for the purposes of achieving efficiency and effectiveness (Håkansson *et al.*, 2009; Håkansson and Waluszewski, 2002). The creation of fits requires adaptive efforts in the process of resource interaction. Drawing on the work by Brennan *et al.* (2003), adaption here can be seen as efforts that are made by organisational units to use or combine tangible resources more efficiently and effectively across firm boundaries, such as assuring better product compatibility and improving the unit cost structure. Such adaptive efforts permits the generation of bandwagon effect “magnified by greater compatibility within a network of complementary items” (John *et al.*, 1999, p. 81).

The adaptation within resource interaction centred around a technological standard gradually leads to a more well-defined pattern of resource interaction, which can be viewed as a technological path. According to Håkansson and Lundgren (1997), a technological path comprises “structure” and “process”, in which the former refers to the combinations of resources controlled by organizational units through organisational relationships while the latter is about relating episodes and events to the interaction between connected tangible and intangible resources. The path-dependent resource interaction signifies that the variety in resource interaction for technological development is restricted (Håkansson and Waluszewski, 2002); in short, “change within constrained opportunities” (Metcalf and Miles, 1994, p. 258). Path dependence has significance for the development of a technological standard and a firm’s competitiveness alike. Within strong path dependence, competing standards tend to be lock-out by a dominant design or a mainstream technology (Hill, 1997; Moore, 1991; Schilling, 1998; Suárez and Utterback, 1995). For firms embedded in the resource interaction based a major technological path, the priority is to exploit the combined (or bundled) resources through collective actions in coordinated ways, so as to increase returns as much as possible (Arthur, 1994; Besen and Farrell, 1994; Håkansson *et al.*, 2009; Kash and Rycroft, 2000).

Research methods

This research adopts a qualitative and case-based approach, which is built on a processual analysis, to address our research questions. This adoption is rationalized by the following considerations. Firstly, the strength of a qualitative case study lies in its ability to deal with contemporary network phenomena of technological innovation with “how” questions (Halinen and Törnroos, 2005; Yin, 2009). Secondly, a processual analysis is considered imperative when knowing that the emergence of a technological standard results from a process of resource interaction where time and temporality are crucial components (Håkansson *et al.*, 2009; Håkansson and Waluszewski, 2002; Pettigrew, 1997). Thirdly, the interactive nature of technological development has its uniqueness (e.g. connection between entities) in each piece of network research, which excludes the employment of quantitative methods characterised by sampling theory (Easton, 1995).

For the feasibility of undertaking network research, delimiting a network boundary is necessary; especially a network can extend boundless (Halinen and Törnroos, 2005). We adopt a technology-bundled net (or a focal net) as

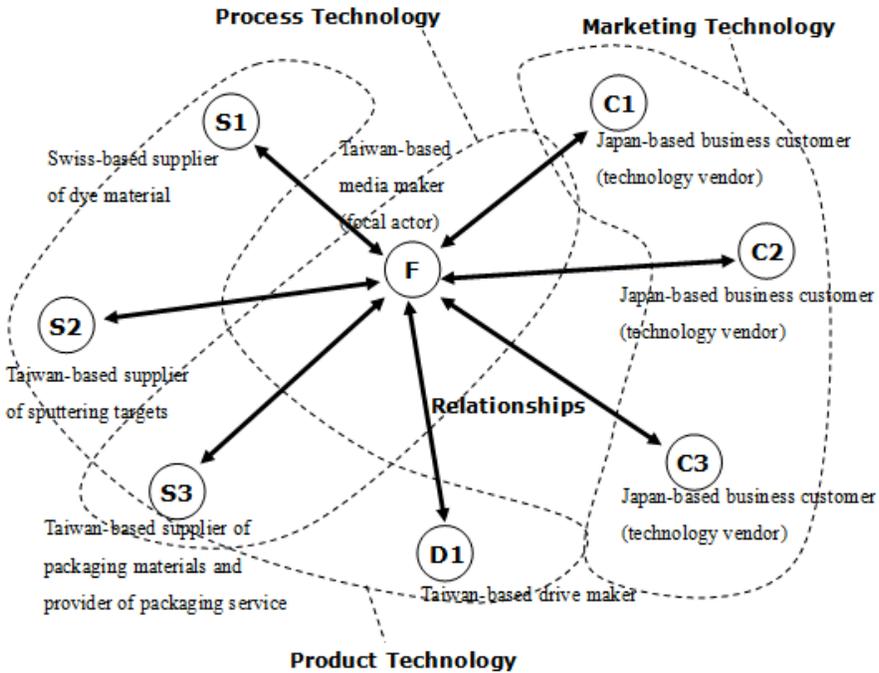
the boundary for this research. This delimitation is made using two criteria. For one criterion, a focal net is able to reproduce a relational structure of bundled resources of different economic actors (e.g. suppliers, customers and complementors) which are important to the promotion of technological standard (Ford and Saren, 2001; John *et al.*, 1999; Metcalfe and Miles, 1994; Ritter *et al.*, 2004). For the other criterion, such a net takes into account the focal actor's important relationships that have impact on technological development and, simultaneously, capture the characteristics of connectedness and embeddedness (Alajoutsijärvi *et al.*, 1999; Anderson *et al.*, 1994).

For the convenience of the empirical investigation, the research purposefully selects the optical recording media industry as the empirical setting. This industry has undergone major technological changes for three times from CD-R (R for recordable) to 1) DVD-R and DVD+R, 2) DVD-R DL and DVD+R DL (DL for double layer; double recording capacity of a DVD-/+R disc) and 3) HD DVD-R and Blu-ray Disc Recordable. This industry is also marked by standards competition, including DVD-R vs. DVD+R and HD DVD-R vs. Blu-ray Disc Recordable. While DVD-R was developed by the DVD Forum (an international standardization coalition), DVD+R was developed the DVD+RW Alliance which has a similar objective of the DVD Form to define, disseminate and verify their own standard. HD DVD-R was also developed by the DVD Forum led by Toshiba while Blu-ray Disc Recordable (or BD-R) was developed by the Blu-ray Disc Association led by Sony. Thus, the optical recording media industry suits the purpose of this research well.

Based on the above criteria of boundary delimitation, the case is the focal net which consists of F, F's business customer relationships with C1, C2 and C3, its supplier relationships with S1, S2 and S3 and a complementor relationship with D1. The names of these companies are not revealed for confidentiality. With the hindsight, we know two facts. One fact is that both DVD-R and DVD+R standards co-exist in the industry and BD-R won out its battle with HD DVD-R as the dominant design in the high-definition optical recording technology. The other fact is that F has experience in producing and selling all types of optical recording media. Therefore, the focal net, which is based on CD-R technology and which contains the characteristic of technology-bundle, serves a proper basis to investigate how new standards (e.g. DVD+R) was introduced into the net and how a standard competed with its rival standard (e.g. HD DVD-R vs. BD-R) in the process of resource interaction within the net. In other words, the reconstruction of the focal net

evolution facilitates addressing our research questions. This technology-bundled net based on CD-R technology is illustrated by Figure 1.

Figure 1. A technology-bundled net based on CD-R



The reconstruction of the focal net evolution mainly relied on interviews with managers and engineers of different organisational units (e.g. R&D, marketing, production and procurement) from the focal net members. Additionally, informants from other companies who had exchange relationships with the focal net members (e.g. F's competitors and minor suppliers) were interviewed. 72 interviews in total were carried out in three stages during a period of time from September 2007 to June 2009. Relevant theory was revisited between each stage and continuous iteration between theory and empirical data permitted a deeper understanding towards the research problems (Dubois and Gadde, 2002). Apart from focusing on dyadic views in the interviews, archival materials (e.g. market research reports and company documents) were consulted in order to produce a more appropriate description of the focal net evolution in which standards

competition took place, covering a history of evolution from 1998 to 2008 (Miles and Huberman, 1994).

In the analysis of empirical data, a particular emphasis was placed on the identification of significant events that occurred in the evolution of the focal net. Significant events are seen as building blocks of an interactive process and they carry change influences, affecting resource interaction towards a certain technological standard (Håkansson *et al.*, 2009; Pettigrew, 1997; Schurr *et al.*, 2008; Van de Ven and Huber, 1990). For the analytical and illustrative purpose, this research employed the concepts of network positions and roles to present the case. A firm being embedded in resource interaction across firm boundaries is argued to occupy a unique network position (Håkansson *et al.*, 2009; Johanson and Mattsson, 1992). In brief, a network position signifies how resources are accessed and how resources used and combined through relational linkages. As for roles of actors, they are seen as the dynamic aspect of network positions; they are able to reveal the dynamism of resource interaction, such as how existing resources are used or combined in a new way (Anderson *et al.*, 1998). Using the concepts of network positions and roles, the resource interaction of the focal net based different generations of optical recording technologies are presented in the next section.

Prior to the case presentation, it has to be noted that this research has two limitations. Firstly, the picture of the reality we present in this study is fragmented although it is built on a large number of interviews with interacting parties (not focus merely on the viewpoints of the focal actor, F) and archival materials. Secondly, the reality we present is still subjective mainly because the informants provided their information according to their individual experience and their subjective interpretations of the social world.

The case: resource interaction based on four generations of optical recording media technologies

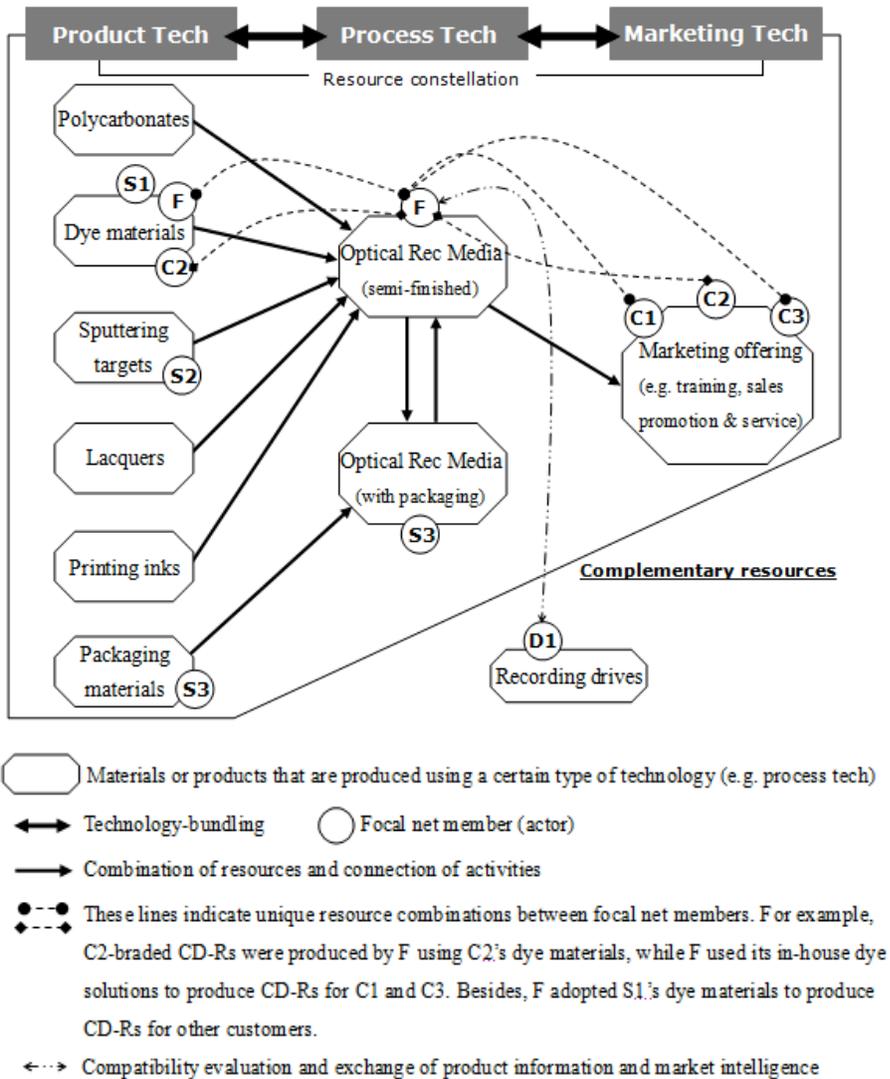
The evolution of the technology-bundled focal net over the past decade is marked by three arrivals of technological changes from CD-R to BD-R and by standards competition, including DVD-R vs. DVD+R, DVD-R DL vs. DVD+DL and HD DVD-R vs. BD-R.

Resource interaction based on CD-R technology

Prior to F's establishment of its customer relationships with C1, C2 and C3 respectively in late 1998, August 1999 and early 2000, CD-R had become the

dominant design for the optical recording media. A common reason for C1, C2 and C3 to approach F was to acquire cost- and quality-competitive CD-Rs to meet the needs from the booming markets. In addition to the relationship with S2, F developed its supplier relationships with S1 and S3 respectively late 1999 and August 2001 and a complementor relationship with D1 in early 1999 to strengthen its competitiveness. The technology-bundled net, which centred around F and which consisted of seven dyads, emerged towards the end of 2001.

Figure 2. Resource interaction based on CD-R



Within the technology-bundled focal net based on CD-R technology, as shown by Figure 2, F, C2 and S3 played multi-roles for their interacting counterparts. In addition to its prudent production management, another advantage of F was its ability to in-house develop dye materials (chemical compounds) for CD-R manufacturing. Dye materials were crucial materials that determined the quality of discs (e.g. compatibility with optical drives) and new product success (e.g. enhancing the recording speed of CD-R by adjusting the formulation of chemical compounds). Apart from F, C2 developed their proprietary dye materials. While F used its in-house developed dye materials to produce CD-Rs for C1's and C3's brand businesses, C2-branded CD-Rs were exclusively manufactured using C2's dye materials. Due to the importance of dye materials, F also introduced S1's dye materials in its mass production in order to diversify its product lines and enhance its knowledge of dye materials. S1's materials initially were not used by F to produce CD-Rs for C1, C2 and C3 but for F's minor customers.

The value that F created for its business customers came not only from its R&D and production competences but also from its cooperation with S2, S3 and D1. For example, in addition to the provision of packaging materials and services, S3 proactively suggested new packaging ideas that allowed F's customers to better serve their end-user markets. Furthermore, although F's relationship with D1 was built on the exchange of information (e.g. market intelligence compatibility between F's media and D1's drives), this relationship enabled the dyad to ensure a better compatibility between their products and to launch their new products in a timely manner.

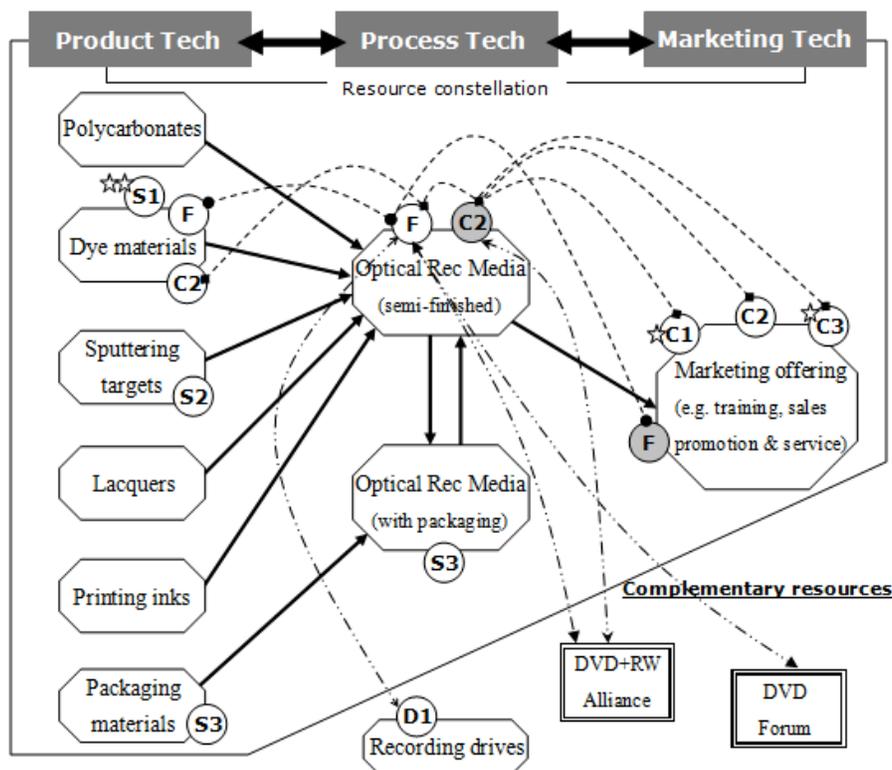
Resource interaction based on DVD-R and DVD+R technologies

The arrival of DVD-R and DVD+R technologies brought about significant changes in resource interaction within the focal net. The obvious changes included F's and C2's new roles. As indicated by Figure 3, C2 played a new role as an "OEM" (original equipment manufacturer) for DVD+R business while it maintained its brand business at the same time. In fact, this OEM business was built on the C2-F partnership, in which actual manufacturing activities were performed by F while C2 provided their proprietary materials, controlled product quality and approached business customers, such as C1 and C3. The past cooperation with F on CD-R business made C2 believe that F was able to handle their DVD+R technology (including key materials) and that their partnership allowed C2 to develop and produce high-quality DVD+Rs ahead its competitors and thus to acquire more OEM orders. By strengthening its relationship with C2 who was a technology leader in the

DVD+RW Alliance, F was permitted to establish its own brand business. This new business was also facilitated by F's ability to produce DVD-Rs using its in-house solutions.

Having the same physical dimension (e.g. diameter and thickness of the disc), the main difference between DVD+R and DVD-R lies in that DVD-R requires a "pre-writing" procedure using special equipment (called "pre-writer") in the volume production. Moreover, in comparison with CD-R manufacturing, each DVD-R or DVD+R disc is composed of two polycarbonate substrates which need to be bonded to each other with an adhesive in a bonding machine. In spite of not being directly compatible with each other, both DVD-R and DVD+R discs, even CD-R discs, can be used (for reading and burning) in almost all optical recording drives (e.g. D1's drives), making many marketers to bet on both standards. Without solely relying on installing new DVD production lines, F transferred some of their CD-R production lines into DVD lines by integrating additional equipment and machines. F viewed this capability as their unique "FMS" (flexible manufacturing system). This FMS permitted F to dynamically react to the requirements from their customers and markets. With their strong R&D, engineering and production capabilities and the partnership with C2, F though they were able to move into the media brand business by setting up a new marketing team in March 2002.

Figure 3. Resource interaction based on DVD-R and DVD+R



- Materials or products that are produced using a certain type of technology (e.g. process tech)
- Focal net member New role of the focal net member
- Combination of resources and connection of activities
- F used its in-housed dye materials to produce both DVD-Rs and DVD+Rs for its newly established brand business
- C2 provided DVD+R products that was manufactured by F using C2-patented dye materials for C1 and C3 as well as its brand business.
- F only provided their DVD+Rs via C2 for C1 and C3
- S1 only supplied CD-R dye materials for F
- Compatibility evaluation and exchange of product information and market intelligence
- Product verification
- C2 joined standardisation activities at the DVD+RW Alliance
- International organisation for standardisation

The decision of setting up the marketing team was made by F's new VP (vice president) who was recruited in July 2001 to devise operational strategies to enhance F's competitiveness. The VP's strategies, however, were not compatible with C1's and C3's expectations and finally resulted in F's fading relationships with C1 and C3 from early 2004 and mid 2003 respectively. The key factors that contributed to the fading F-C1 relationship included the VP's reluctance to purchase C1's used CD-R lines in their US-based factory and to expand more CD-R production capacity for C1 and the marketing team's unilateral CD-R price markup. In the face of fierce competition in the CD-R business, almost all focal net members agreed to that migrating to the DVD business could improve their profitability. But, F thought that purchasing used CD-R lines brought them nothing but burdens while C1 thought that getting more CD-R output from F and producing DVD-Rs themselves in Japan were the best ways to strengthen their competitive stance. As for the discontinuation of the F-C3 relationship, this was mainly because C3's production orders were neither large nor stable. F's preferred to save more production capacity for their brand business.

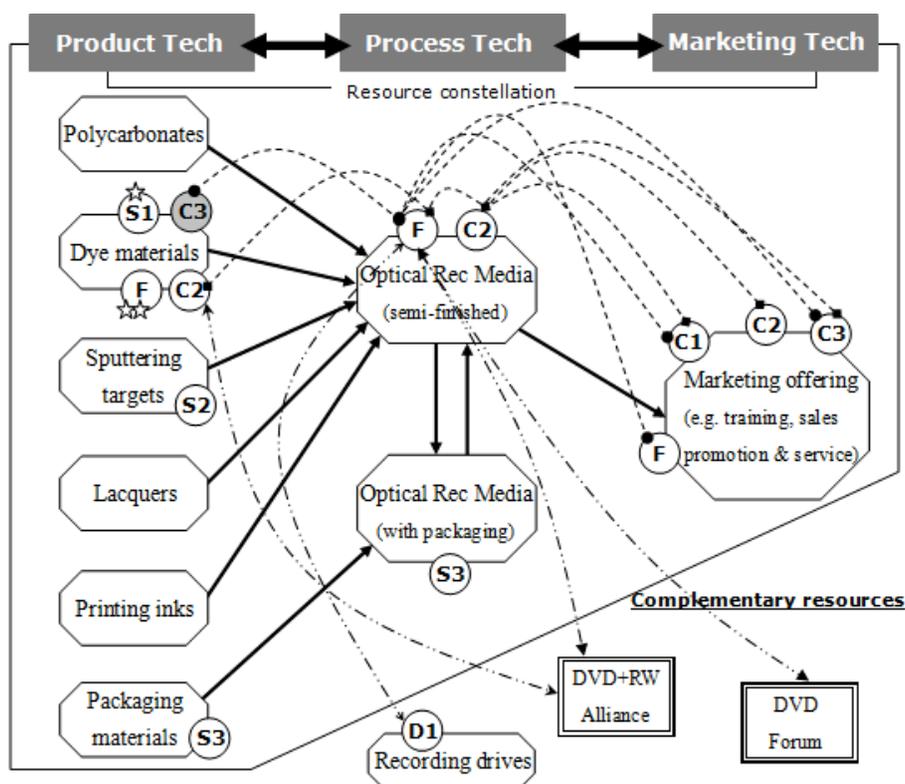
Despite F's fading relationships with C1 and C3, their interdependence existed in a form of indirect connection via C2 who partnered with F. In addition to acquiring DVD+Rs from C2, C1 and C3 purchased DVD-Rs from F's competitors. Meanwhile, the focal net exhibited a co-existence of cooperation and competition. F also retained stable relationships with S1, S2, S3 and D1. One important thing here was that S1's dye business remained in the CD-R area. When the attention of industry competition was focused on high recording speed CD-Rs, S1's materials were adopted by almost all media makers because the materials could easily suite a variety of manufacturing conditions. Besides, S1's partnership with an UK-based consultancy and an equipment provider, as a turn-key solution, made S1's dye materials as dominant materials in CD-R manufacturing. But following this were a plethora of CD-R makers and the severe price war; which in turn, urged major media makers and marketers to introduce DVD-R and DVD+R. Although S1 was able to develop new materials for DVD manufacturing, the media using their new materials failed to get verified by either the DVD Forum or the DVD+RW Alliance for political reasons.

Resource interaction based on DVD-R DL and DVD+R DL technologies

Significant changes in resource interaction with the focal net were occasioned by the introduction of DVD-R DL and DVD+R DL technologies. Prior to

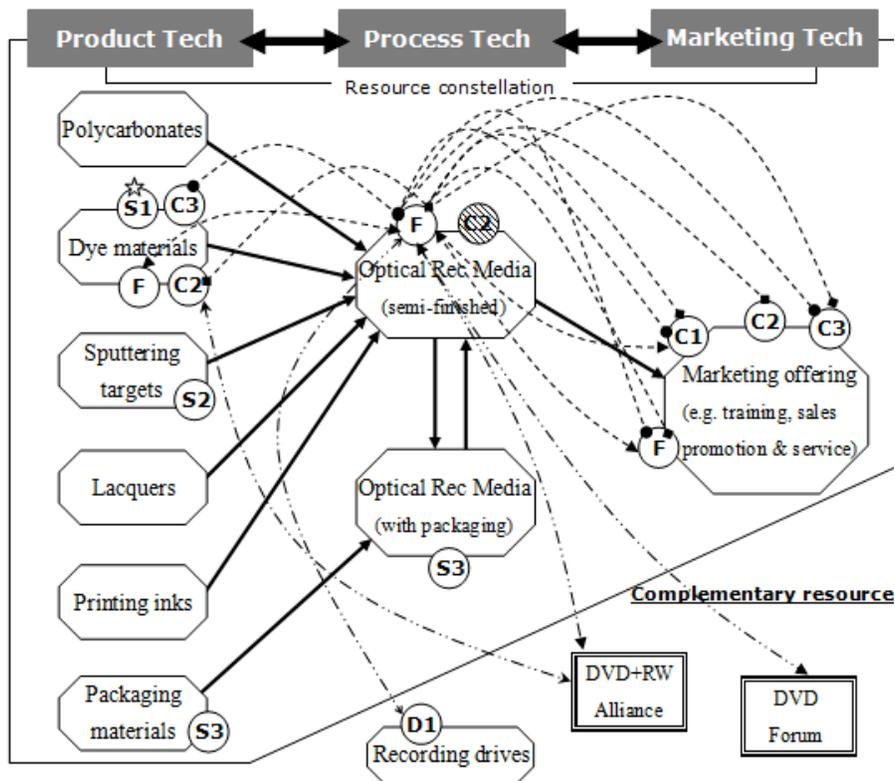
this, changes in resource interaction were also initiated by F's encounter with a bottleneck in upgrading its DVD-R to higher recording speed using in-house solutions in mid 2004. As shown by Figure 4, after being turned down by a Japanese supplier of dye materials F turned to C3 to acquire their newly developed dye materials. Despite the discontinuation of the F-C3 relationship, C3 was happy to re-cooperate with F who possessed large production capacity that could boost their new business as a supplier of dye materials for DVD manufacturing. The adoption of C3's materials allowed F to re-gain DVD-R OEM orders from C1 because the DVD-Rs using C3's materials could diversify C1's product offerings in the market. Meanwhile, C1 and C3 still acquired F-made DVD+Rs from C2.

Figure 4. Resource interaction after F's encounter of a technical barrier



- Materials or products that are produced using a certain type of technology (e.g. process tech)
- Focal net member New role of the focal net member
- Combination of resources and connection of activities
- F used C3's dye materials to produce DVD-Rs for C1, C3 and its brand business
- C2 maintained its partnership with F, providing DVD+R products for C1, C3 and themselves
- S1 only supplied CD-R dye materials for F
- F used its in-house dye solutions for CD-R and DVD+R manufacturing
- Compatibility evaluation and exchange of product information and market intelligence
- Product verification
- C2 joined standardisation activities at the DVD+RW Alliance
- International organisation for standardisation

Figure 5. Resource interaction based on DVD-R DL and DVD+R DL



- Materials or products that are produced using a certain type of technology (e.g. process tech)
- Focal net member New role of the focal net member Stop playing the role
- Combination of resources and connection of activities
- F used C3's dye materials to produce DVD-Rs for C1, C3 and its brand business
- F used C2's dye materials to produce DVD+R and DVD+R DL for themselves as well as C1, C2 and C3.
- F used its in-house dye materials to produce DVD+R DL and DVD-R DL for themselves and C1
- ☆ S1 only supplied CD-R dye materials for F
- Compatibility evaluation and exchange of product information and market intelligence
- Product verification
- C2 joined standardisation activities at the DVD+RW Alliance
- International organisation for standardisation

The F-C2 partnership continued after the arrival of DVD-R DL and DVD+R DL technologies at the focal net. Among a very limited number of makers, F and C2 were capable of developing their materials and processes for DVD DL manufacturing.

However, the partnership encountered a great challenge especially after DVD+R 16X (the technological limit of DVD+R) was launched to the market, which left the makers and marketers of DVD+R with little benefits but competition for lower price. It was difficult for C2 to sustain its partnership with F because their profitability was significantly squeezed by price competition on existing products (DVD+R). This was partly because C2's sale team was not so capable of managing their brand and OEM businesses which comprised a number of products based on the existing and new technologies. Moreover, the advantage of the C2-F partnership was gradually counteracted by C2's main competitors based in Japan and Taiwan. Eventually in December 2005, as indicated by Figure 5, C2 gave up its role as OEM and their business customers (e.g. C1 and C3) were taken over by F.

Resource interaction based on HD DVD-R and BD-R technologies

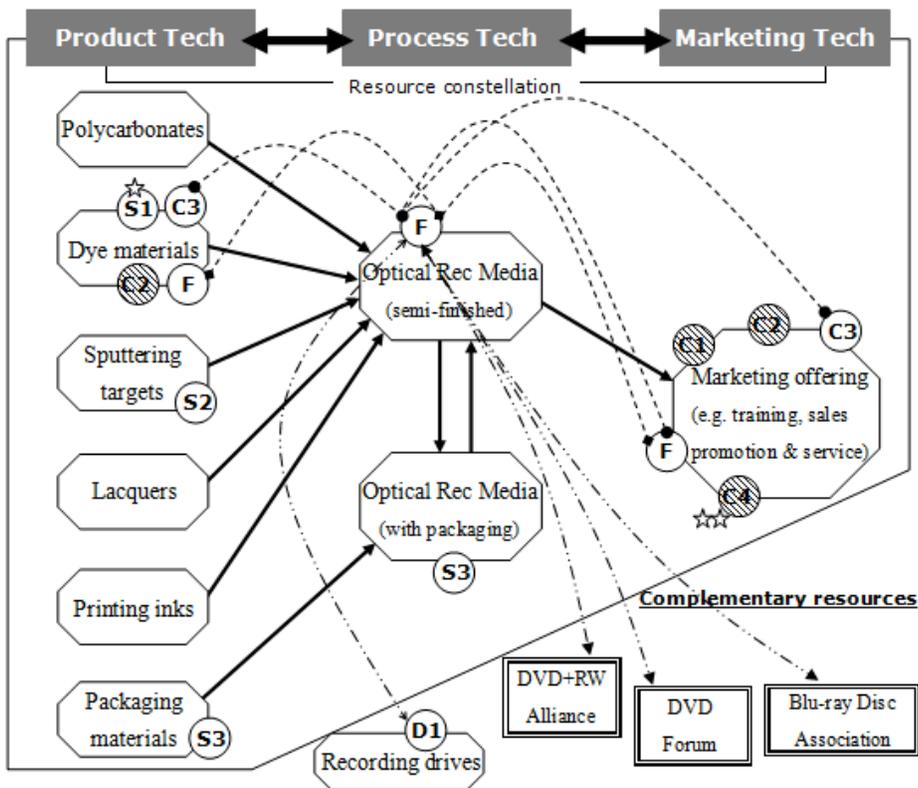
Similar standards competition as DVD+R vs. DVD-R took place on the stage of high definition (HD) optical recording media; it was the rivalry between HD DVD-R and BD-R. Foreseeing the promising future of HD recording media and positioning as a leading optical recording media maker, F kicked-off their BD-R project and HD DVD-R project respectively in November 2004 and August 2005. It was much difficult to produce BD-R than HD DVD-R owing to high technical and capital barrier. For those who wanted to produce BD-R, installing new production lines became a must. Before being able to volume produce BD-R in March 2007, F had achieved a breakthrough in their development of HD DVD-R in April 2006. They were capable of producing cost-competitive HD DVD-Rs using in-house developed dye materials without significantly altering the existing DVD production system. However, there were still few market demands for either HD DVD-R or BD-R at that time.

The market uncertainty resulted in F's attitude of sitting on the fence towards rivalry between HD DVD-R and BD-R, although F's R&D urged to aggressively promote their HD DVD-R so as to create a lead and enjoy higher profitability. F's hesitance remained unchanged until C4 (a Japan-based technology leader of HD DVD) approached them in June 2007 to cooperate on HD DVD business. In addition to doing OEM business with C4, F also jointly promoted HD DVD standard with C4 using their branded HD

DVD-R. F's cooperation with C4, however, was short-lived (see Figure 6). Without having the support from major studios and retailers for HD DVD standard, C4 finally decided not to make and market HD DVD players and recorders in February 2008. This decision forced F to discontinue its HD DVD-R business, even though they were able to combine the existing resources from its suppliers (including S2 and S3) with their in-house solutions to produce good quality HD DVD-Rs.

Prior to C4's discontinuation of HD DVD business, radical changes occurred in F's relationships with C1 and C2 in mid 2007. Perceiving little advantage in either HD DVD-R or BD-R and experiencing declined profitability in DVD+R and DVD+R DL businesses, C2 decided to exit from the optical recording media industry. Unlike C2's situation, C1 repositioned them as a media maker (also an OEM) specialised in BD-R manufacturing because they thought being a patent member in the Blu-ray Disc Association while having manufacturing experience enabled them to gain more advantage than marketing optical recording media. Subsequently, C1 sold their media brand business to a US-based technology vendor. This strategic move by C1 disconnected their relationship with F.

Figure 6. Resource interaction based on HD DVD-R and BD-R



- Materials or products that are produced using a certain type of technology (e.g. process tech)
- Focal net member ● New role of the focal net member ⊘ Stop playing the role
- Combination of resources and connection of activities
- F used C3's dye materials to produce DVD-Rs for themselves and C3
- ◆---◆ F used its own solutions to provide its brand business with all types of optical recording media, including Blu-ray discs.
- ☆ S1 only supplied CD-R dye materials for F
- ☆☆ F once provided HD DVD discs for C4 using its in-house dye materials. However, their cooperation only lasted for several months due to C4's exit from the industry
- ←--- Compatibility evaluation and exchange of product information and market intelligence
- ←--- Product verification
- ←--- C2 joined standardisation activities at the DVD+RW Alliance
- ▭ International organisation for standardisation

Discussion

Theoretical discussion

The empirical result allows us to argue that technological standards as well as firms co-evolve in a process of interaction between tangible and intangible resource entities across firm boundaries. More specifically, technological standards are the products of resource interaction in certain network settings and they are “emergent properties of the process of economic change” (Metcalf and Miles, 1994, p. 244). A firm’s competitiveness by adopting a new technology or bridging technological is determined by how its resources are used in relation to other firms (Afuah, 2000; Håkansson and Waluszewski, 2002; Powell *et al.*, 1996). Thus, the process of resource interaction defines the success for technological standards and firms alike.

Our empirical case permits the development of three insights of standards competition from a resource interaction perspective. Firstly, the success or survival of a technological standard needs to be built on the bundles of product, process and marketing technologies that form an interfirm structure (or a net). Our processual analysis reveals that the interaction between the bundled technological resources creates a critical and solid basis on which a standard can rest to prosper, such as developing new products (with enhanced recording speed or new packaging styles). In other words, releasing derivative products based on a standard in the markets to generate increasing returns can be fulfilled through collective activities of a technology-bundled net (Arthur, 1994; Hill, 1997; Moore, 1991; Tabrizi and Walleigh, 1997).

Secondly, the co-existence of technological standards hinges on the compatibility in resource interaction. We refer “the compatibility in resource interaction” to that a physical resource used or combined by an external organisation for a certain purpose can also be used or combined by the same organisation or other organisations for another purpose. For examples, S2’s and S3’s materials can be used by F’s (or F’s competitors’) production department to produce either CD-R or DVD-R. We find that it is this higher compatibility in resource interaction that allows different standards of optical recording media to co-exist. This insight offers an alternative account for the dynamics of the optical recording media industry, which are characterised by the inter-standard (e.g. DVD-R vs. DVD+R) competition and inter-generation (e.g. CD-R vs. DVD-R vs. DVD-DL vs. BD-R) (Yamada and Kurokawa, 2005).

However, we have to point out that forming a technology-bundled net or having the compatibility in resource interaction does not guarantee the success

or survival of a new technological standard. This finding can be demonstrated by the HD DVD-R standard being defeated by the BD-R standard. From a technical point of view, HD DVD-R can be produced without altering that much as BD-R in the existing production system. There is high compatibility in resource interaction between HD DVD-R and DVD-/R DL. In this sense, HD DVD-R results from a path-dependent evolution of the optical recording media industry (Arthur, 1994; Håkansson and Lundgren, 1997); but it was not selected as a dominant standard in this evolutionary process of resource interaction. The finding confirms an important notion made by Araujo and Harrison (2002) that path dependence does not imply either fatalism or determinism because the direction of the paths is influenced by strategically reflexive and temporally oriented actors who can make sense of their own positions, interests and entities. Thus, this finding leads to our third insight that the path-dependent evolution of technological standards is interaction-determined.

Managerial implications

The empirical findings allow us to elicit two managerial implications. The first implication relates to the importance of compatibility in resource interaction. In the evolution of technology-based nets or networks, technological standards and firms are two crucial but inseparable components. We argue that the linkage between standards and firms lies in resource interaction; in which “compatibility” is a central dimension that is closely related to the success of the both. In addition to our above notion of compatibility in resource interaction, firms need to further take into account the history of intangible resources while developing strategies for interaction. Extending from Cooper (1979) where he emphasizes the compatibility between intangible resources (e.g. R&D, management and engineering skills) in new product development, we find that interaction history needs to be included because it produces both constraints and opportunities for present and future actions (Håkansson *et al.*, 2009). This can be exemplified by S1’s failure to bridge technological changes after CD-R. Their failure results not from technical but political issues where the DVD Forum (a standardisation coalition) tried to make their DVD-R and HD DVD-R standards incompatible with S1’s materials because of S1’s image of price-killer and turkey provider in CD-R. To better understand the compatibility in resource interaction, studying interaction episodes and events becomes important.

The second managerial implication is to achieve positional flexibility in the face of standards competition or co-existence of standards. We consider

positional flexibility here as that a firm is able to adjust its role(s) performed for interacting counterparts by necessary mobilisation of resources across firm boundaries in order to better exploit the aggregate resources based on a certain technological standard. A good example of exerting positional flexibility is C2's new role as an OEM and its ability to mobilise F's resources, so as to acquire production orders from the competitors (e.g. C1 and C3) in their brand business. We also find that the change of role(s) can be facilitated by the logic of technology-bundle, which stresses to think interactively rather than linearly. Such an interactive thinking has an advantage of dealing with network complexity characterised by co-existence of cooperation and competition. By achieving position flexibility, Firms being embedded in technology-bundle nets can dynamically respond to emergent needs from the process of resource interaction, such as technological change.

Conclusions

This research is in accord with a truism that “no business is an island” (Håkansson and Snehota, 1989). Firms have to become integrated part of resource interaction based on certain technological standards so as to survive, grow and prosper through individual and collective actions in technology-based networks. On the other hand, competitiveness of firms, in terms of their effectiveness and efficiency, is often the source of successful technological standards. In the business environments where technological uncertainty, market uncertainty, and competitive volatility prevail (Mohr *et al.*, 2005), firms have to confront the challenges from rapid technological change and even convergence of different technologies (e.g. computing technology and telecommunication technology are converged in many portable devices). This rapidly changing business landscape requires firms to continuously review how their resources are used and combined with the resources of other firms, so as to increase the returns from certain technological standards on which they bet; and thus, to maintain their competitiveness.

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