Technological Forecasting & Social Change 78 (2011) 1397–1411

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Factors for winning interface format battles: A review and synthesis of the literature

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ARTICLE INFO

Article history:
Received 6 August 2009
Received in revised form 9 March 2011
Accepted 14 March 2011
Available online 16 April 2011

Keywords:
Interface format
Standards battles
Dominant design
Technology battles
Technology selection

ABSTRACT

The literature on selection of interface formats is fragmented and does not provide an overall framework in which all relevant factors are included. Current frameworks are incomplete and focus on a subset of the total set of factors. In this paper we develop a more complete overview of factors based on the available literature. First, we perform an extensive literature study of 127 publications, resulting in 29 factors for format dominance. Second, we group the factors into five categories: characteristics of the format supporter, characteristics of the format, format support strategy, other stakeholders, and market characteristics. Third, we perform a meta-analysis and we specify the direction of each factor on format dominance. This results in a framework that facilitates assessing the chances that an interface format achieves dominance. We demonstrate that this framework is more complete than previous frameworks. The framework can be used by both researchers and practitioners to understand historical and current format battles as well as acceptance of formats without direct competitors.

1. Introduction

What will be the fourth generation mobile telecommunication format? Does Mobile WIMAX (IEEE 802.16e) have a good chance of becoming an accepted format for wireless telecommunication? Which specifications for flat screen television will we use in the future, plasma or LCD? Early interface format battles include the now classic QWERTY vs. Dvorak battle. Similar battles continue to emerge time and again. They have in common that a set of interface specifications competes with one or more other sets of interface specifications. For firms, consumers and other parties involved, it is important to have insights regarding the chance that a specific set will dominate. For firms the issue is which format they support and implement in their products. Dominance of a format is determined by customers who buy products in which the format is implemented. They will prefer to spend their money on products in which a format is implemented that will turn out to be the winner; otherwise they may face problems related to interoperability with other products and/or lack of future support for their products. In this paper, we develop a list of factors influencing the chance that an interface format will dominate.

These battles typically are between specifications of interfaces. Many authors use the term 'standard' to refer to such interface specifications. Krechmer [1] classifies them as compatibility standards — standards that 'define the interface between two or more mating elements that are compatible rather than similar, e.g., a plug and a socket, a transmitter and a receiver' [1: 7]. However, the term standard may be confusing because other categories of standards also exist, for instance, minimum quality and safety standards, variety reducing standards, and information and measurement standards [2]. Moreover, in some cases the specification is laid down in a set of standards instead of just one standard, as in the case of GSM [3]. Instead we might consider using the term dominant design [4,5], but this term is used much broader. It may refer to a product's design specifications that define the product category's architecture [6], a 'set of features' [7: 1], 'core design concepts' [8: 11], 'trajectory' [4: 208], or 'a way of doing things

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0040-1625/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.techfore.2011.03.011

which is manifested in a product' [9: 6]. Thus, designs include entire products [10] as well as (sets of) features of products [9]. Therefore we use a more definitive term: interface format. We define an interface format as a set of codified specifications for the interrelations between entities in order to enable them to function together [based on 11,12]. We address these interface formats from a market perspective [13] focusing on situations in which the format competes for dominance in the market with one or more other formats: a format war. At the supplier side, the question is which of the available formats each supplier implements in his products. At the customer side, the outcome of the format war results from customer purchase behavior: which formats were implemented in the products they bought? We will also make use of literature that uses the terms (dominant) standard or (dominant) design for our concept 'interface formats'.

'Dominant' may have different meanings, like 'widely accepted' [14: 496] or, more specific, (a) the most closely competing alternative design has abandoned the active battle; and/or (b) a design has achieved a clear market share advantage over alternative designs, and this advantage is increasing [15], (c) 'the highest level of market acceptance for a significant amount of time' [9: 6], or (d) more than 50% of new installations use the technology [4]. For defining 'dominant', we take the 50% and 'new' of Suarez [4] because it is the most specific about market share, and add 'for a significant amount of time' [9: 6] because market share may change after some time and day to day fluctuations should be ignored. We add 'in a product category' in order to leave the possibility that different dominant formats emerge in different product categories or niches at the same time. Of course, also the same format may dominate in different product categories or niches, an example is the Advanced Video Coding format H.264 which is used for both Blu-ray disc players, YouTube videos, digital video broadcasting, and video conferencing.

For firms in such 'format wars', the stakes are high [16] and can even result in firms leaving the market. The outcome of the battle is accompanied by a high amount of uncertainty, which has only increased since the amount of time that it takes to fight a format battle has decreased rapidly over time — the battle for one railroad track width format took many decades, the battle for a high definition video disc format lasted for only a couple of years. Scholars have pointed to many factors that affect the outcome of such battles [4,5,16]. However, the literature is fragmented and does not provide us with an overall framework in which all relevant factors are included. The framework developed by Suarez [4], for instance, applies mainly to the information and communication industry. In this industry, network externalities exist for many products and factors such as the installed base and the availability of complementary goods become extremely important. In other industries, other factors may be more important, which results in an overlap of factors. Studies that do propose frameworks also tend to be incomplete and focus on a subset of the total set of factors. An example is provided by the quite extensive literature on the battle between the Betamax, Video 2000 and VHS formats for video recording [17–26]. Each author mentions a different, although overlapping, set of factors that have influenced the outcome of this battle. There is a need for a more complete overview of factors that can be used to assess the chances that a format achieves dominance. Then we may be able to better understand interface format dominance which can decrease the level of uncertainty.

Our objective is to develop such a list based on the available literature. In this list, as many factors for format dominance as possible are taken into account. Also, since we include factors that can have both a positive and a negative effect on the chances that an interface format will dominate; we specify the direction of the effect between each factor and format dominance.

In this paper, based upon a literature review, we distinguish between five categories of factors for dominance of interface formats. Based on similarities between the factors, we group them under the five categories, resulting in a framework for format dominance. The contribution of this paper lies in the integration of the different theoretical perspectives into a common framework that is more complete than existing frameworks. We begin by exploring several theoretical perspectives on format dominance in Section 2, leading to five categories of factors. Subsequently, in Section 3, we describe methodologically how we develop the list of factors. In Section 4, we present the results of a systematic search of the literature for factors that belong to each category identified in Section 2. Subsequently, we determine the direction of influence for each factor on format dominance. In Section 5, we discuss our results and in Section 6 we present our conclusions.

2. Theoretical perspectives on interface format dominance

The dynamics in industries that lead to interface format dominance has been studied from multiple perspectives and disciplines. According to evolutionary economists, the survival of a firm is the result of a process of natural selection [27]. Technology evolves through periods of incremental change until at some point in time a major breakthrough is introduced in the industry. These so called technological discontinuities increase the uncertainty in the industry and usually change it considerably [28]. As a result a new technological paradigm emerges consisting of 'its own concept of progress based on its specific technological and economic trade-offs' [29: 148] and often leads to new markets and applications [30]. Within a new paradigm, different technological paths can be developed resulting in designs that compete with each other for dominance [31]. Such a design can be an entire product or an interface format. Our study focuses on the period beginning with the technological discontinuity and ending when one interface format has become dominant.

Scholars in the field of industrial economics have studied the dynamics of industries and the role of standards in the emergence of new markets. They developed a three stage life-cycle model of technology according to which in a new industry at the end of the first, 'fluid' phase a standard emerges that remains stable over time [7,32: 45]. In terms of this model, we focus on the first stage. Within the industrial economics field, a separate stream of literature focuses on network economics. Network economists have emphasized the importance of market characteristics, particularly the existence of so-called network externalities, stating that the benefits of a technology for an individual user increase when the number of users grows [33,34]. Most markets in which network externalities exist are 'two sided' in that they consist of complementary goods for which the format defines the interface [35: 304]. Examples include the markets for VCRs [19] and video game consoles [36,37]. When more complementary goods are available for

the interface format this has a positive effect on the installed base of that format [38]. In network markets, users, producers and other stakeholders follow each other in their technology choices because of information advantages, scale effects, and the availability of complementary goods [39]. Network economists demonstrate that as a consequence of such effects the interface format that has an initial advantage over other formats tends to increase its advantage, resulting in a winner-takes-all situation. The costs to switch to another format increase and as a consequence people get locked into a particular format [9,16,19,34,40]. Network economists emphasize that not always the best format wins the competition [41].

Institutional economics focuses on strategic behaviors of firms to increase the possibility that their interface format becomes dominant [19]. In essence, institutional economists suggest that individual firms can have an influence on the outcome of a format battle. Especially in the early stages of a competition, the strategy with respect to the position of formats in the market is of great importance [42]. This is also emphasized by Suarez [4], who stresses the importance of strategic maneuvering in the first stage of the battle for dominance. A format support strategy can be followed which helps firms to promote their own technology and at the same time prevents the adoption of competing technologies. Strategic factors such as pricing and distribution strategy of products, in which a format is implemented, influence market dominance of that format [43], provided these are matched with the firm's resources and are effectively implemented. Another aspect emphasized by institutional economists is the time of introduction of products (in which the format has been implemented) in the market [5,10] where it is argued that entering early can have both advantages and disadvantages [44]. Other strategic factors include a firm's appropriability strategy [45], and strategic marketing communications. Patents may apply for interface formats. Bekkers, Duysters, and Verspagen [46] found 120 essential patents for the GSM specifications. A firm can support a format by means of an open licensing policy and, as such, encourage imitation by competitors, which will in general increase the chances of this format to become dominant. This strategy has the drawback that the firm itself will often reap lower benefits from the format [47–49]. An open policy contributed to the success of the RISC technology over the CISC technology in the US microprocessor industry [42]. On the other hand, protecting formats from imitation, by means of patents or asking license fees increases revenue percentage for patent holders but diminishes its chances of becoming dominant and thus its chances of actually reaping these benefits. Strategic marketing communications (pre-announcements) are used to increase installed base and to discourage producers to implementing other formats in their products and users from adopting products in which rivals' formats have been implemented [16,50]. In the video gaming industry, for example, the Nintendo 64 system was announced more than two years before it actually became available [36].

Scholars in the field of technology management have developed several frameworks of interface format dominance, integrating concepts from both industrial and institutional economics [4,5,9]. We follow this literature by distinguishing between factors that can be influenced by the firm ('firm-level factors' [4: 275]) and factors that are given in specific industries and can hardly be influenced by individual firms ('environmental factors' [4: 275]). In our framework, the environmental factors are the market characteristics. From the evolutionary economics and network economics literature, we learn that specific *market characteristics* exist, such as the level of uncertainty and network externalities that affect format dominance and lock-in, which can hardly be influenced by individual firms. These factors do not directly influence the chances that one particular format achieves dominance because these factors have the same value for each of the formats competing in the market, but influence the likelihood that one of the formats will become dominant and the pace at which dominance will be reached. For instance, the existence of network externalities will increase the likelihood that one format will reach dominance and a high level of uncertainty in the market will decrease the pace at which dominance will be achieved. Also, these factors have a moderating effect on other factors [4]. For instance, the existence of network externalities will increase the effect of a current installed base on format dominance. Based on the institutional economics literature, two categories of firm-level factors can be distinguished: *characteristics of the format supporters* (encompassing for each of the supporting firms its resources, including its size and financial strength), and the *format support strategy* (including timing of entry of the first products for which the format is used, and appropriability).

Within the technology management field, a separate stream of literature focuses on standardization. Standardization literature distinguishes between three stages in the standardization process: development, selection, and implementation [51]. We focus on the second stage; selection. A distinction can be made between market-based and committee-based standardization [13] where the former can result in a standard that achieves dominance as an outcome of competition in the market and the latter can result in a standard that has been agreed upon in a committee. Agreement in a committee, however, does not automatically lead to market acceptance [52]. Several studies have paid attention to the adoption of standards by individual organizations [53–55], and to the role of standardization organizations on these adoption decisions [12]. Several authors have examined format battles [36,56], while other authors focus on the economic impact of standards [2,57]. Some authors in this field also study the topic of standard selection from a game-theoretic perspective [13,58,59]. In line with the standardization literature we add the category *characteristics of the format*. The characteristics of the format encompass the compatibility the format enables, the availability of complementary goods, and technical characteristics. Compatibility guarantees connectivity of the product in which the format has been implemented with complementary goods and with products in which earlier (generations of) formats have been implemented [60]. Technical characteristics refer, for instance, to specific innovative elements, which can help a format to become technologically superior and increase its chances of reaching dominance [6]. Scholars in the area of standardization also mention the influence of *other stakeholders* in the format battle. Often, stakeholders other than the group of standard supporters (such as competitors, regulatory agencies, standardization committees, and conformity assessment bodies) have an influence on which format will become dominant.

In Table 1, we summarize the different literature streams discussed above, the categories of factors for interface format dominance upon which the different literature streams focus, and the main representative studies. For each literature stream we briefly discuss their view towards format dominance. The order of the streams of literature in the table is no indication of their importance. In Fig. 1, we present a graphical overview of the different streams of literature that are used in this research to form a

Table 1
Theoretical positioning of studies on format selection.

Literature stream/theoretical approach	Factors for format dominance	View towards format dominance	Representative studies
Evolutionary economics	Industry mechanisms (such as uncertainty, rate of technological change)	Focus on the speed and likelihood of format dominance.	Utterback and Abernathy 1975 [31]; Tushman and Anderson 1986 [28]; Anderson and Tushman 1990 [15]
Network economics	Market mechanisms (such as network externalities)	Formats achieve dominance through environmental factors that cannot be influenced by the firm and that moderate the influence of firm level factors.	Farrell and Saloner 1985 [61]; Katz and Shapiro 1985 [34]; Arthur 1989 [27]; Liebowitz and Margolis 1994 [62]
Institutional economics	Characteristics of the firm (such as financial strength) Strategy (such as timing of entry)	Individual firms can increase the possibility that their format will become dominant by the possession of superior resources and by strategically positioning their format.	Willard and Cooper 1985 [63]; Cusumano, Mylonadis and Rosenbloom 1992 [19]; Garud and Kumaraswamy 1993 [11]; Khazam and Mowery 1994 [42]
Technology management/standardization	Characteristics of the format (such as compatibility, complementary goods, technological superiority) Other stakeholders (such as regulator, suppliers of complementary goods) (and market mechanisms, characteristics of the firm, strategy)	Formats achieve dominance through firm level factors and environmental factors. Environmental factors also moderate the influence of some firm-level factors.	David 1985 [41]; Lee, O'Neal, Pruett and Thoams 1995 [9]; Schilling 1998 [5]; Schilling 2002 [38]; Suarez 2004 [4]

theoretical perspective towards format selection. The figure illustrates from which theoretical stream the literature draws. So, technology management makes use of concepts from institutional and network economics.

3. Methodology

In our search for specific factors, our starting point was a review paper of the literature [4]. We arranged the factors mentioned in that article in a list. For every new publication that we analyzed, we searched for factors that had not been mentioned before and we included them in the list. We then classified the factors in order to identify those factors that were closely related or overlapping in meaning. This provided us with a shorter list of unique factors. From the initial article, we moved to the publications cited by the author (backward search) and looked for factors mentioned in those publications. We also reviewed publications that

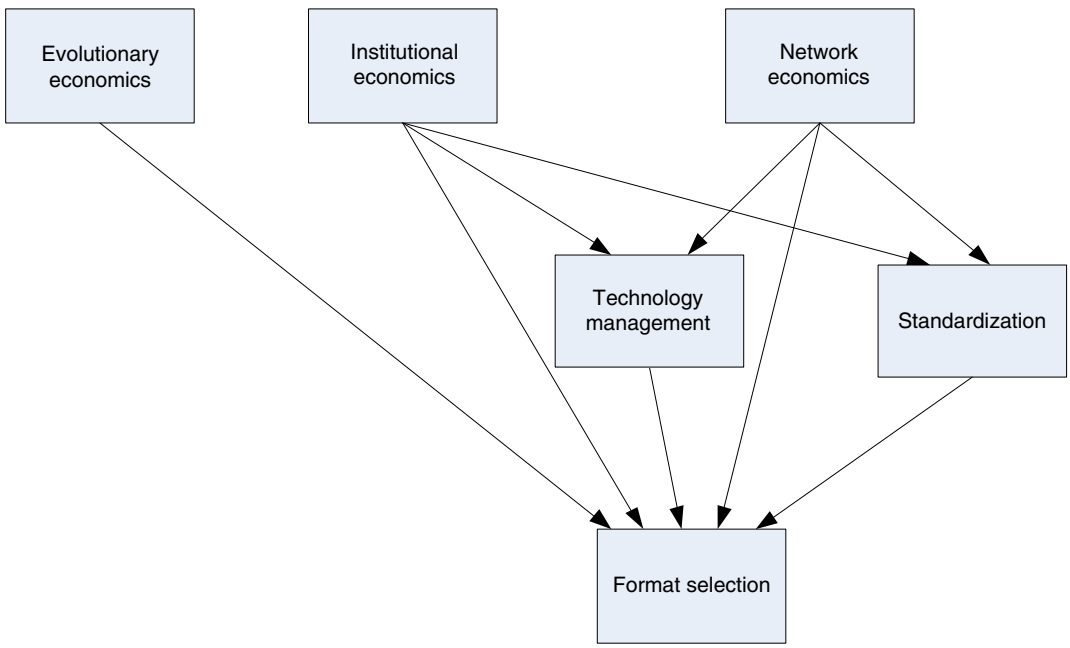

Fig. 1. Inheritance of theoretical streams of literature forming a perspective towards format selection.

cited the article (forward search). The process was then repeated for these publications until no new factors were found. The forward search was performed by a citation analysis via the ISI Web of Knowledge scientific database. This process is similar to that applied in meta-analyses on transaction cost theory [64] and organizational innovation [65]. Publications that did not explicitly mention specific factors were excluded from our list. In some cases, the same factor was mentioned under different names. When this occurred, we selected one name. Based on similarities between the factors we grouped them under the five categories presented in Section 2. To guarantee that the list of factors is as complete as possible we did not only restrict ourselves to published research studies but also analyzed practitioner literature, unpublished sources, and PhD theses. Taking into account multiple different types of publications also decreases publication selection bias [66].

Apart from determining the factors that were mentioned in a particular publication, we also determined the direction of the relationship between each factor and format dominance. By comparing the directions reported in each study, we came to an understanding of the theoretical relationship between the factors and format dominance. If each study suggested a particular direction, we took that direction. It appeared that for some factors, both positive and negative impacts were suggested in the literature. For example, 38 studies suggested that early entry into a market of the first products in which a format has been implemented will result in a higher chance of achieving dominance while eight studies suggested the opposite. To determine the direction of the factor in such cases, we selected the publications that were based on a quantitative empirical test, and we applied the vote counting principle on those specific studies [67,68], we computed the average of the effect sizes reported in each study. We had three categories of outcomes: significantly positive, significantly negative, or no significant relation. Finally, we totaled the number of studies found in each category which provided us with an empirically supported relationship between the factor and format dominance. For some factors this procedure did not lead to a conclusion. In those cases we concluded that the factor had two possible directions. We then describe the conditions under which these factors have a positive or negative direction.

4. Results

We analyzed 127 publications in which one or more factors were mentioned to reach a set of 29 factors for interface format dominance and to determine the direction of the relationship between each factor and format dominance. If the 127 publications are equivocal about the direction we selected the publications that were based on a quantitative empirical test (15) and we applied vote counting to determine the relationship.

The papers have been published in management journals (such as the Strategic Management Journal and Management Science) and economics journals (such as the American Economic Review and the Rand Journal of Economics). However, most papers have been published in a journal in the area of technology management; Research Policy.

Our search for factors resulted in a list of 29 factors. A matrix that relates these factors to the publications in which they were found as well as the full list of publications that were taken into account in the analysis is available as a supplementary file. This matrix demonstrates that each reviewed publication provides only a limited number of factors, ranging from 1 to 23, with an average of 6.33.

Fifteen out of the 127 publications report quantitative empirical data. In Table 2, we give an overview of the 15 quantitative empirical studies that were taken into account in this study.

In Table 3, we present the results from the study. In this table, we specify the direction of the relations as they are described in the literature (both theoretical and empirical) and the direction of the relations reported in the quantitative empirical papers in particular. Based on these data, we determined whether the effect of each factor on format dominance is positive or negative. Below we discuss each factor.

4.1. Characteristics of the format supporter

The first group of factors relates to the strength of the interface format supporter (when formats are supported by multiple companies, we refer to the complete group of supporting companies). The stronger the format supporter, the better are the chances of the supported format becoming dominant.

1. *Financial strength*, as defined by Willard and Cooper [63], is not only the current financial condition of the parent corporation, but also its future prospects. When introducing a format, financial resources can be used to compensate start-up losses [79] including the cost of developing the format; a group of format supporters that has a higher financial strength than competitors can endure longer periods of low earnings due to low prices of products in which the interface format is implemented, as well as spend more on marketing of both the format itself and the products in which it is used [80] and thus will have a higher chance of setting a dominant format. Sixteen studies mentioned this factor as positive.
2. *Brand reputation and credibility* plays a significant role in the users' selection of a format. Past performance in setting dominant formats has a positive impact on the attitude to new proposals [81]. Also, a group of format supporters with a good reputation will find it easier to attract other stakeholders to join the group [82] resulting in an increase in the format's installed base. Thirty-nine studies suggested a positive relation between the factor and format dominance.
3. *Operational supremacy*: when a group of format supporters is composed in such a way that it is able to exploit its resources better than competitors, it has an advantage over them which will positively influence its chances of reaching dominance with the format. This advantage is called operational supremacy [38]. Operational supremacy can be reached, for instance, by the possession of a superior production capacity [83]. A technological advantage of one or more members of a group of format supporters can increase the chances that their format will achieve dominance [81]. Twenty-three studies mentioned this factor as having a positive effect.

Table 2
15 Empirical studies revealing factors for interface format dominance.

Authors	Independent variables	Dependent variable as measured by	Type of Statistical analysis	Type of industry
Agarwal et. al. [69]	Learning orientation Financial strength	Firm survival	Correlation (n = 1180)	Disk drive industry
Christensen et. Al. [6]	Timing of entry Financial strength Flexibility	Firm survival	Regression (n = 453)	Disk drive industry
Dranove et. Al. [70]	Complementary goods	Market share	Regression (n = ?)	Optical disc storage industry
Klepper et. al. [71]	Financial strength	Firm survival and market share	Regression (n = 83, 134)	Television industry
Majumdar et. al. [72]	Current installed base Previous installed base Bandwagon effect Rate of change Financial strength	Market share	Correlation (n = 40)	Telecommunications industry
Mitchel [73]	Timing of entry Previous installed base Learning orientation Financial strength	Market share	Correlation, regression (n = 98, 216)	Diagnostic imaging industry
Schilling [38]	Current installed base Timing of entry Learning orientation Complementary goods	Lock out	Correlation, regression (n = 89)	Several product categories including PC operating software and video game hardware
Shankar et. al. [74]	Network externalities Complementary goods Pricing strategy Marketing communications	Market share	Regression (n = 64)	Video game industry
Srinivasan et. al. [75]	Appropriability strategy Network externalities Learning orientation	Probability of emergence	Correlation, regression (n = 63)	Office products and consumer durables
Suarez et. al. [10]	Timing of entry	Firm survival	Regression (n = 83, 95, 121, 105)	Typewriter industry Automobile industry Television industry Picture tube industry
Tegarden et al. [14]	Timing of entry Pricing strategy	Market share	Regression (n = 21–202)	Personal computer industry
Tripsas[76]	Number of options available Learning orientation	Market share	Regression (n = 154)	Typewriter industry
Wade [77]	Bandwagon effect Technological superiority	Market share	Regression (n = 51–57)	Microprocessor industry
Willard et. al. [63]	Timing of entry Current installed base	Firm survival	Multiple statistical analyses (n = ?)	Television industry
Zhu et. al. [78]	Network externalities Marketing communications Switching costs Financial strength	Format adoption	Regression (n = 1394)	Internet standards

4. *Learning orientation:* Duncan and Weiss [84] describe the learning capabilities of the firm as the process by which knowledge about action–outcome relationships and the effects of the environment on these relationships is developed. Failure to invest in learning can increase the likelihood of a format being locked out [38]. With learning, we refer both to the know-how; the core capabilities, and the extent to which the firm can acquire new knowledge-absorptive capacity. The absorptive capacity refers to both technological know-how (the ability to generate technological breakthroughs) and market pioneering know-how (whether these technological breakthroughs can be commercialized) [69]. Learning from experience can increase the chances that dominance will be reached. For instance, in the television industry, firms that were also producing radios survived longer and had higher market

Table 3
Direction of impact of factors on dominance of interface formats.

	Theoretical direction			Empirical direction			Direction
	# studies suggesting a positive effect	# studies suggesting a negative effect	# studies that do not specify a certain direction	# studies reporting a significant positive effect	# studies reporting a significant negative effect	# studies reporting no significant effect	
Firm level factors	Impact on format dominance						
Characteristics of the format supporter							
1 Financial strength	16						+
2 Brand reputation and credibility	39		1				+
3 Operational supremacy	23						+
4 Learning orientation	47	1	2	3	1	1	+
Characteristics of the format							
5 Technological superiority	39		2	1			+
6 Compatibility	30		6				+
7 Complementary goods	54		3	3			+
8 Flexibility	10						+
Format support strategy							
9 Pricing strategy		33	3		2		−
10 Appropriability strategy		23	9		1		−
11 Timing of entry	1	32	19	1	5		∩
12 Marketing Communications	40		3	2			+
13 Pre-emption of scarce assets	10		1				+
14 Distribution strategy	24		4				+
15 Commitment	9						+
Other stakeholders							
16 Current installed base	42		1	3			+
17 Previous installed base	7		2	2			+
18 Big Fish	20						+
19 Regulator	30		5				+
20 Antitrust laws		13	2				−
21 Suppliers	23						+
22 Effectiveness of the format development process	11						+
23 Network of stakeholders	13						+
Environmental factors	Impact on the speed and likelihood of format dominance						
Market characteristics							
24 Bandwagon effect	32						+
25 Network externalities	65	2	2	2	1		+
26 Number of options available		4	1		1		−
27 Uncertainty in the market		9	1				−
28 Rate of change		5	2			1	−
29 Switching costs		20	20		1		−

share than those that did not: they were able to make use of their prior experiences in the radio industry [71]. Therefore, the learning orientation of the group of format supporters plays a positive role. We found 47 theoretical studies suggesting a positive effect of which three quantitative empirical studies confirmed the suggested effect. However, one study [76] shows that the prior experience of incumbents can also have a negative influence on market share as such experience restricted the incumbent in committing to a new format. This study demonstrates a situation in which firms invest too much in core capabilities and too little in absorptive capacity. Thus, a group of format supporters can, by investing in learning, increase the chances that its format reaches dominance, provided it invests in both core capabilities and absorptive capacity.

4.2. Characteristics of the format

A format that is superior compared to other formats has a higher chance of becoming dominant. This superiority may include:

5. *Technological superiority*: Schumpeter [85] defines technological superiority of a design as having features that allow this design to outperform other designs. On the other hand, David [41] emphasizes that the most technically advanced format does not necessarily become the dominant one. Thirty-nine studies suggested a positive relationship between this factor and format dominance.

6. *Compatibility*: another characteristic of a format is the compatibility it enables. Compatibility concerns the fitting of interrelated entities to each other in order to enable them to function together [12]. Horizontal compatibility concerns the fit between functionally equivalent objects (e.g., two Lego bricks or two telephones) When a format is backwards compatible the format is designed in such a way that the technology in which it is implemented is compatible with technologies in which the previous generation of the format has been implemented. For example, formats for analog color television have been specified in such a way that the color signal could be received by black and white television sets. By making a format backwards compatible the chances that it will achieve dominance increases [86] as it can make use of the previous installed base of the format. Thirty studies suggested a positive relation between the factor and format dominance.
7. *Complementary goods*: complementary goods are those other goods needed to successfully commercialize a certain format [45]. Similarly, Farrell and Saloner [87] recognize that the interchangeability of complementary goods creates demand-side economies of scale. Unsurprisingly, when an interface format is used in many complementary goods, this increases demand for the format [88]. In 54 theoretical studies it was suggested that a positive effect exists between the number and variety of complementary goods in which the format is used and the chance that the format will achieve dominance. This was supported by three quantitative empirical studies.
8. *Flexibility*: the flexibility of a format refers to the incremental cost and time needed to adapt the format due to new developments such as changes in customer needs or technological improvements [89]. Technology management literature indicates that flexibility facilitates the adaptation of a product to customer requirements, and thus has a positive influence on the installed base of products [89]. Standardization literature addresses the topic of flexibility as well and implicitly assumes that a more flexible format adds to technological superiority and thus to dominance [90,91]. We found ten theoretical studies suggesting this positive effect.

4.3. Format support strategy

In this section, we survey the range of strategies companies can use to win a format battle.

9. *Pricing strategy*: this refers to all actions taken to create market share through strategically pricing the products in which the format has been implemented. Sellers may be willing to temporarily price below cost in order to build an installed base [92,93] and thus make the format more attractive. Such penetration pricing [34] can also temporarily be used to block possible entrants [87]. We found 33 studies suggesting that a low product price will contribute to format dominance, with which a further two quantitative empirical studies agreed.
10. *Appropriability strategy*: this factor refers to all actions that are undertaken by firms to protect a format from imitation by competitors [9]. An open licensing policy will result in an increase in the installed base. We found 23 theoretical studies suggesting a positive effect; a more open appropriability strategy will increase the chances that a format will achieve dominance. For instance, Sun's open systems strategy led to the success of Java [56].
11. *Timing of entry*: timing of entry is the point in time at which the first products in which the format is implemented enter the market. Early entry may be essential for achieving dominance [44,73,94] although there is no consensus in the literature here. Early entry can contribute to dominance of the format by creating an installed base of products in which the format has been implemented [10,34,95]. On the other hand, early entrants are hindered by a lack of market information and have to make a comparatively higher initial investment, thereby limiting their ability to support their interface format going forward [38,95]. So, early entrants should have sufficiently deep pockets to exploit the advantage of an installed base [19,45,83]. We found one study suggesting a positive effect and 32 studies suggesting a negative effect. Further, the quantitative empirical papers are not unequivocal. In five out of the six quantitative empirical studies, early entry is considered to contribute positively to dominance. We believe that the relationship between timing of entry and format dominance is not linear. Christensen et al. [6] and, in particular, Schilling [5,38] argue that there is an inverted U-shaped relationship between timing of entry and dominance. Christensen et al. [6: S208] speak of a 'window of opportunity' within which it is optimal to enter the market.
12. *Marketing communications*: customer expectations play an important role in format battles [16] and, therefore, marketing communications are important for gaining greater market share. In the early phase of a battle, pre-announcements of the format itself or announcements of company intention to implement the format in its products can be used to discourage users from adopting rivals' formats prior to the introduction of products in which one's own format has been implemented [50,87]. For instance, in the DVD format war, the DIVX preannouncement may have slowed down the adoption of the DVD format [70]. At later stages, marketing communications, like advertising or public relations, remain important. They can be used to form expectations that a format will become dominant [50]. These expectations can become a self-fulfilling prophecy in the sense that the format that is expected to become dominant will actually become the dominant format [96]. However, conflicting announcements can confuse potential customers and result in credibility problems [42]. We found 40 studies suggesting a positive relationship.
13. *Pre-emption of scarce assets*: firms that are able to capture scarce assets at an early stage, thus denying them from other players, are able to create a competitive advantage [97], and can use this advantage to increase the chances of their format becoming dominant. An example of an asset is an important manufacturer of the product in which the format is used. The group of format supporters can exclude rivals by establishing a relationship with that manufacturer. We found ten studies that mentioned this factor as a positive factor.

14. *Distribution strategy*: this factor refers to the extent to which a firm pursues a strategy which increases the strength of its distribution system [based on 63]. A good distribution strategy for the products in which the format is implemented can make the difference in accelerating the acceptance of a technology [98]. A good distribution strategy was mentioned in 24 studies as a factor that positively influences format dominance.
15. *Commitment*: for an interface format to become dominant in the market, it is important that it obtains sufficient attention and support from each of the actors in the group of format supporters to survive the early stages, when the return on investment is usually low [63,99]. When uncertainty is high and a high number of competing formats exist, companies tend to commit themselves to multiple formats at the same time. Then the group of format supporters can include companies that are not fully committed to one format. This divided commitment is likely to decrease a firm's market share position [14] and may be negative for the group of format supporters of which the firm is a member. We found nine studies suggesting a positive relationship between commitment and format dominance.

4.4. Other stakeholders

The fourth group of factors relates to stakeholders other than the group of format supporters.

16. *Current installed base*: many authors mention the installed base as a factor. Farrell and Saloner [87] defined it as the number of users of a technology. Others focus on the technology itself [100] and then the installed base is a measure of the number of units actually in use (as opposed to market share, which only reflects sales over a particular period). Since we focus on the implementation of interface formats in a technology, we define the current installed base as the number of units of technologies in which the format is implemented actually in use. When a market is affected by network externalities, the installed base has an effect on the adoption of the format. In 42 of the studies we analyzed, this factor was cited as having a positive effect.
17. *Previous installed base*: formats that rely on a previous generation of technology have an installed base consisting of the units of that technology actually in use. The users of these units might upgrade to the new format [87,100]. We found seven studies suggesting that a higher previous installed base will increase the chances that a format will achieve dominance.
18. *Big fish*: a big fish is a player (other than the group of format supporters) that can exercise a lot of influence by either promoting or financially supporting a format or by exercising buying power that is so great that this will tip the balance for the format to become dominant in the market [10]. An example of a big fish is IBM, who set the MS DOS format for personal computers. However, IBM's support is no guarantee for success — despite their support for the Token Ring format, it failed to become the dominant format for Local Area Networks. We found 20 studies which suggested that the existence of a big fish will increase the chances of the format achieving dominance.
19. *Regulator*: the regulator can prescribe certain formats (e.g., right/left side driving, railroad tracks) [10] in which case the result of a format battle is no longer a pure market outcome [81]. Thirty studies mentioned the regulator as a factor.
20. *Antitrust laws*: the judiciary can prohibit certain formats from becoming dominant through antitrust laws. An example of this is Microsoft's dominance with its Windows operating system. In 2004, the European Commission ordered Microsoft to make the source code of Windows interface specifications available to its competitors so that they could develop complementary software for Windows [101]. Before this judiciary intervention, only Microsoft could write software for Windows such as the Windows Media Player and offer that software with Windows. After this intervention the market share of both Windows and the complementary software written by Microsoft decreased since both could no longer make use of each other's installed base. The cost of switching from Windows to a competing operating system decreased considerably since it was not necessary anymore to switch complementary software. Another example can be found in the US instant photography market, where a federal court ordered Kodak to leave the market because it had violated the patents of Polaroid. This led to the failure of Kodak's format for instant photography [102]. This factor was mentioned in 15 studies, 13 of which suggested a negative relationship between judiciary intervention based on antitrust laws and format dominance.
21. *Suppliers*: other suppliers that adhere to a format are the companies that produce complementary goods or services in which the format is applied [45,80]. Format supporters can, by influencing these suppliers, increase the chances that their format will achieve dominance [50]. They can follow a system lock-in strategy where they attract as many suppliers of complementary goods to their network as possible [103]. For example, in the early '90s, both IBM and Microsoft attempted to encourage firms to develop software for their respective operating systems as they competed to make OS2 or Windows the dominant format [50,104]. In the battle for a video format, this factor also played an important role. JVC had access to a larger range of manufacturers of complementary goods than Sony [19] and these manufacturers also offered a more diverse range of VHS devices [79]. In 23 studies, this factor was mentioned, suggesting that the more a firm can attract other suppliers of complementary goods, the higher the chances are that the format will achieve dominance.
22. *Effectiveness of the format development process*: interface formats can be developed in different ways, for instance, by a single company, in a consortium of different companies, or in committees of an official standardization organization. Differences in, for instance, decision rules, process management and stakeholder involvement impact the effectiveness of the process, for example, in terms of its duration [12] or the quality of the resulting specifications. This influences the potential of the format becoming dominant [105]. In 11 studies, this factor was mentioned and each study suggested a positive relationship between the effectiveness of this process and the chances that the format achieves dominance.
23. *Network of stakeholders*: several characteristics of the network of stakeholders supporting a format can have a positive influence on the chances that the format will achieve dominance. We emphasize the diversity of the network of stakeholders.

A format that is supported by a diverse network (in which stakeholders represent each relevant product market in which the format can be used) will have a high chance of achieving dominance [106]. This certainly was the case in the battle for a Digital Video Disc (DVD) format, where hardware manufacturers cooperated with movie studios to establish it[1] [70]. Thirteen studies suggested that the diversity of the network will contribute to the chances that a format will achieve dominance.

4.5. Market characteristics

Market characteristics cannot be influenced by the firm, they just exist, but impact the outcome of format battles.

24. *Bandwagon effect*: when some users have chosen to implement a certain solution to a matching problem, others tend to choose the same solution; often for reasons of availability of information [12]. This so-called bandwagon effect positively affects the likelihood that dominance of one format will be reached in the market. This factor was mentioned in 32 studies.
25. *Network externalities* describe the effect that the utility an individual user derives from consumption of a good increases with the number of other agents consuming the good [34]. A typical example is the fax machine — the more machines the more possibilities for interconnection, provided that common interface formats are available to enable interconnection [107]. Also, the utility of a format increases when the amount and variety of complementary goods that is available for that format increases. If an interface format possesses a higher installed base than its competitor and the network externalities are high, that format will have a higher chance of achieving dominance. Most studies (65) suggest a positive effect of network externalities on the likelihood that one format will achieve dominance. However, two studies suggest a negative effect and one study has empirically proven this negative effect. Here, it was argued that the existence of the network effects will induce more firms to introduce incompatible formats early on since each firm will want to take advantage of the lock-in effects which increase the number of formats that exist next to each other [94].
26. *Number of options available.* The number of competing interface formats plays a significant role in the potential market share of a format [76]. Four studies suggested that a larger number of competing formats in a market lower the chances for each of them to become dominant.
27. *Uncertainty in the market*: When the uncertainty in the market gets too high, firms and customers are not willing to take the risks attached to choosing one particular format and postpone their decision [108,109]. This decreases both the likelihood that dominance of one format will be reached and the speed at which this format will achieve dominance. This negative effect was suggested in nine studies.
28. *Rate of change* refers to the speed of evolution within a specific industry both with respect to the technology and the market [83]. A high speed has a negative effect on the emergence of a dominant format [110]. The rate of change refers, for instance, to the speed at which new generations of the format are being introduced. When this speed is high it affects the desirability of committing to any format [9]; the competing formats may be changed again before anyone has obtained dominance and this may make users reluctant to commit themselves. In five studies, it was suggested that a high rate of change negatively affects the likelihood that a format will achieve dominance.
29. *Switching costs* are costs required to switch between competing formats [4]. In many cases these cost include the procurement of new products (including complementary goods) in which the new format is implemented such as software for a PC with another operating system. If the format provides the interface between technology and man, the switching costs may include 'mental changes' such as learning to use a new keyboard layout [41]. When switching costs are high, it will take relatively longer before a new format becomes dominant. This negative effect was suggested in 20 studies.

5. Discussion

In Table 4, we compare our results with the factors mentioned in prior frameworks for interface format dominance [4,5,9].

Our list contains more factors, Schilling [5] and Lee [9] both included 15 factors, Suarez [4] 17. Suarez distinguishes firm level factors and environmental factors which are related to each other. In our framework, five categories with a total of 29 factors are included. We notice that seven factors that were not mentioned in the three prior frameworks were included in our list; flexibility, commitment, previous installed base, effectiveness of the format development process, network of stakeholders, bandwagon effect, and uncertainty in the market. Thus, it appears that our framework is more complete then existing frameworks.

Among the 127 publications that we reviewed, (quantitative and qualitative) empirical publications represented about one third. The largest share was captured by theoretical publications (58%). Practical publications represented the smallest share (8%) (Fig. 2). Only 15 publications use quantitative empirical data, indicating that further quantitative empirical research is definitely needed in this field, particularly for factors that have so far mainly received only theoretical treatment (such as the flexibility of the format and the network of stakeholders), although some of those factors (such as commitment and uncertainty in the market) are difficult to measure empirically.

Table 3 shows that some factors have only rarely been mentioned in the literature. This may be due to several reasons. Some publications focus on one specific factor or a set of specific factors, thereby excluding others. Other publications focus on a specific case study, and not all factors apply. For instance, in many cases regulation does not apply. Another possible explanation is that

[1] The importance of network diversity also seems to be important in the more recent battle between HD DVD and Blu-Ray for a high definition digital video disc format.

Table 4
Factors mentioned in prior frameworks for interface format dominance.

Factor \ Prior interface format dominance framework	Lee et al. [9]	Schilling [5]	Suarez [4]
Characteristics of the format supporter			
1 Financial strength			■
2 Brand reputation and credibility		■	■
3 Operational supremacy	■		■
4 Learning orientation	■	■	■
Characteristics of the format			
5 Technological superiority	■	■	■
6 Compatibility	■		■
7 Complementary goods		■	■
8 Flexibility			
Format support strategy			
9 Pricing strategy		■	■
10 Appropriability strategy	■	■	■
11 Timing of entry	■	■	■
12 Marketing Communications	■	■	■
13 Pre-emption of scarce assets	■	■	
14 Distribution strategy	■		
15 Commitment			
Other stakeholders			
16 Current installed base		■	■
17 Previous installed base			
18 Big Fish	■	■	■
19 Regulator	■	■	■
20 Antitrust laws		■	
21 Suppliers			■
22 Effectiveness of the format development process			
23 Network of stakeholders			
Market characteristics			
24 Bandwagon effect			
25 Network externalities	■	■	■
26 Number of options available	■		
27 Uncertainty in the market			
28 Rate of change	■	■	
29 Switching costs	■		■

authors were simply not aware of certain factors and, therefore, did not mention them. Gradually, more factors will be discovered. We have investigated whether the total number of factors per publication increases with the year of publication, see Fig. 3. The data provide a first indication of a possible positive correlation between the number of factors per publication and the year of publication. Apparently, over time more factors are discerned.

We started this research with distinguishing between five theoretical perspectives towards interface format dominance; evolutionary economics, network economics, institutional economics, technology management, and standardization. In Fig. 4, for every theoretical perspective that we distinguish, we present how many publications (of the 127 publications found through our literature study) draw on that perspective.

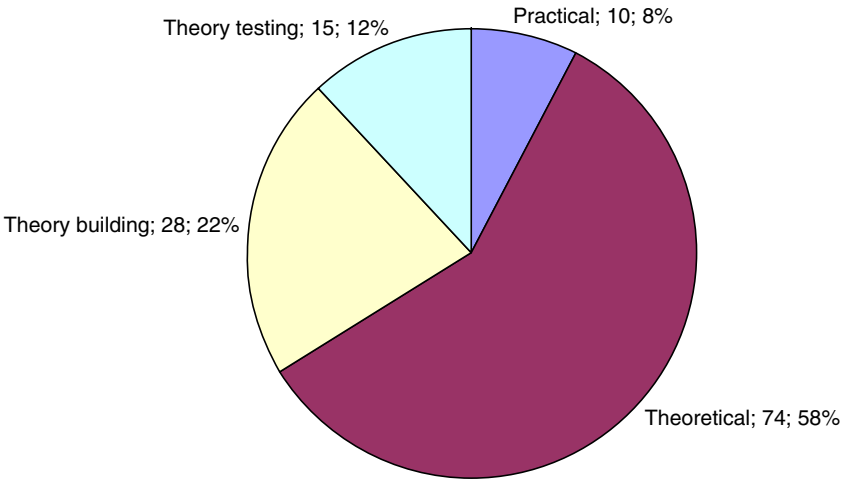

Fig. 2. Breakdown of publications by publication type.

Most publications draw on one of the theoretical perspectives discussed in Section 2. However, we have found 15 publications that view format dominance through other theoretical lenses including social networks and transaction cost economics. Thus, research on format selection is multi-disciplinary.

6. Conclusion

In this study we performed an extensive literature study of 127 publications, identifying 29 factors for market dominance of interface formats. Based upon a literature review, we distinguish between five categories of factors for format dominance: characteristics of the format supporter, characteristics of the format, format support strategy, other stakeholders, and market characteristics. By performing a meta-analysis, we specified the direction of each factor on format dominance. This resulted in a framework for interface format dominance.

The contribution of this paper lies in the integration of the different theoretical perspectives on interface format dominance by developing a common framework that includes more factors than existing frameworks. In this sense it provides a more holistic view and the set of factors can be used as a more complete checklist for analyzing format battles. Thus, researchers can use our framework to analyze format battles and as such gain a deeper insight into these battles. These cases may include the cases already described in the literature; using our lens may show to what extent our approach adds to the understanding of these cases. Not all factors apply in each battle and per battle the importance of the relevant factors will differ. By applying the framework to different historical cases of format battles, weights for factors might be established. Discovering such weights would make it easier to predict the future dominance of interface formats, a topic of future research. A possible approach to establishing such weights is by letting experts assign weights to

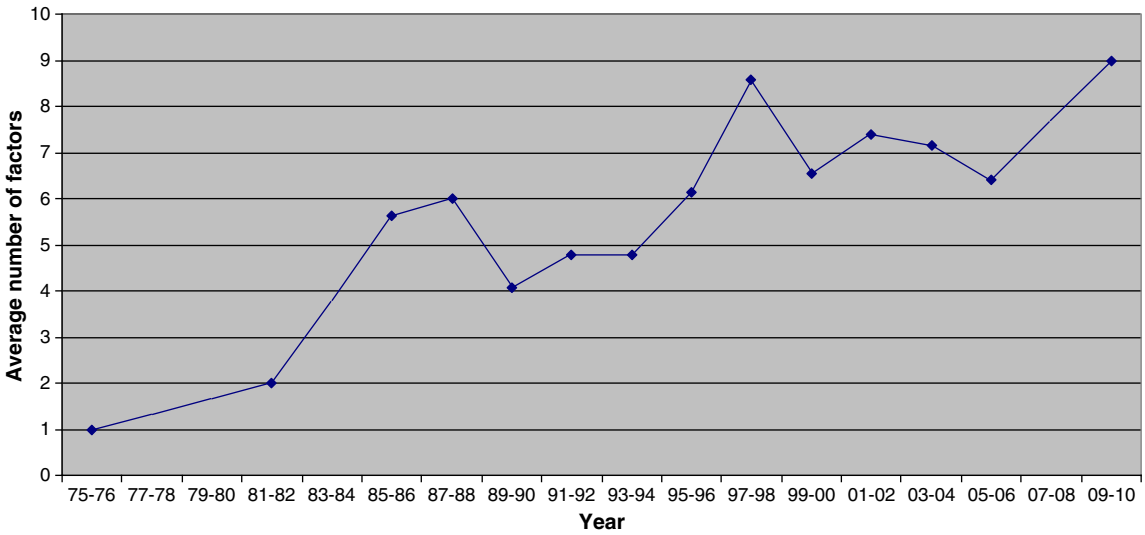

Fig. 3. Average number of factors for format dominance mentioned per two year period.

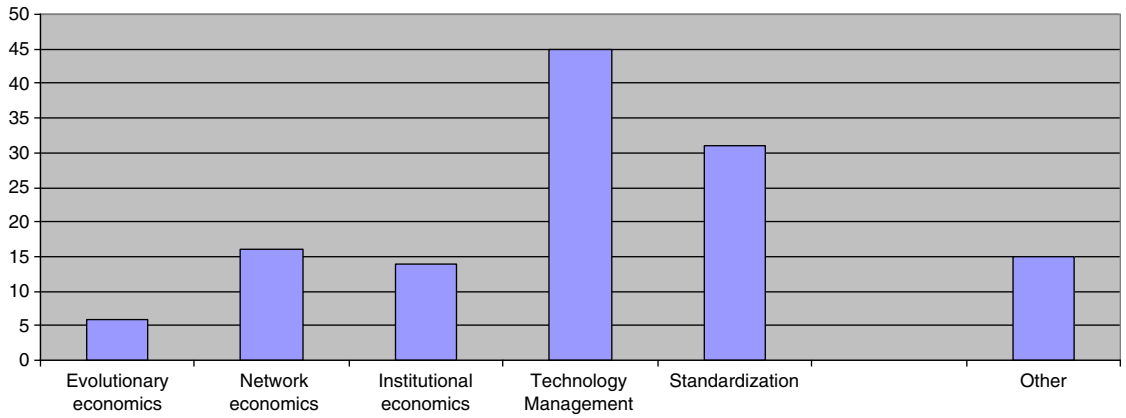

Fig. 4. Number of publications found per literature stream.

factors. In this way, weights per factor per case can be determined. Next, different cases can be compared to each other and then the question is if certain patterns in weights exist. For instance, cases in the same product market might more or less share relevant factors and weights per factor. Once discovered, this would make it easier to predict the outcome of format battles in such product markets. Also, it can be assessed whether weights of factors might be contingent on the type of format. Practitioners can use our framework as a guide to analyze current battles between competing interface formats. Suppliers of products in which the format can be implemented can use the framework as a basis to influence the outcome of these battles. Potential users of these products can decrease the uncertainty attached to the decision as to which format should be supported by determining the value of each factor (in terms of high, low, etc.). By doing so, they are forced to closely evaluate every factor, which will result in a better understanding of the case. Then, they can make a better informed choice as to which format should be supported. To fully exploit this framework, a comparison should be made with the competitor's format, for which the same framework can be used. Also, when analyzing a format battle one should take into account as many factors for format dominance as possible because some factors may point to a particular format winning while at the end of the day that format does not win. In this case, other factors may point to competing formats winning. For instance while BETAMAX was considered technologically superior to VHS, the latter format achieved dominance partly because JVC (the promoter of VHS) formed more alliances with manufacturers of complementary goods [19].

We focus on format battles but we expect our framework can also be used for analyzing acceptance of formats that do not have a competitor. Also then market acceptance of the format is not self-evident, many formats have been developed that did not manage to achieve acceptance by the intended user group.

Our study focuses on interface formats which can be seen as compatibility standards. To which extent our findings also apply to other standards might be a topic of future research. A limitation of this study is that we focus on the influence of individual factors on format dominance though in format battles a set of interrelated factors can affect dominance. Schilling [5] for instance showed that the current installed base and the availability of complementary goods reinforce each other. Also, environmental factors can moderate the influence of some firm-level factors. For example, when a market is characterized by network externalities, the format that has a higher installed base than its competitor has a higher chance of achieving dominance [4]. Studying format battles through case studies could reveal other possible combinations of factors for dominance. Furthermore, a practical limitation exists with respect to the applicability of the framework as a checklist in the decision making process. Theoretically, if every firm that participates in the battle applied the framework, the competitive advantage for the individual firm could decrease to a negligible level. However, at the same time, the uncertainty with respect to which format will win is reduced, leading to a higher speed and likelihood of format dominance.

Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.techfore.2011.03.011.

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