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PLATFORM COMPETITION PROCESSES: A FUTURE RESEARCH OUTLOOK

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Abstract
Platform competition for market share can have broad ranging implications within or across industry sectors. It is subject to the complex and changing socioeconomic context in which it unfolds. Three trends provide evidence for this: (i) the number of relevant factors for platform market dominance is steadily increasing, (ii) industries converge, and (iii) historically platform competition cases take less time to unfold. These trends suggest that the delays involved in how relevant factors influence the market outcome of platform competition have been changing ultimately influencing the trade-offs managers face in platform development and competition. Nevertheless, none of the existing frameworks in the literature is equipped to account for delays explicitly. Hence, no empirical studies based on these frameworks take this directly into consideration either. The article argues that a way forward is the systematic use of modelling and simulation when applying these frameworks to platform competition cases and outlines the research agenda this opens up.
Keywords: simulation, platforms, competition, dynamics, frameworks

INTRODUCTION

Platform-based markets have become highly important in several industries, high tech in particular, with a growing number of platforms and firms whose activities revolve around them (Eisenman et al., 2011; Zhu and Iansiti, 2012; Gawer and Cusumano, 2014; Thomas et al., 2014). Platforms are essential to the operation of most technological systems, such as ICT networks, because they enable the interconnection of various technological components and subsystems. The increasing importance of platforms calls for deepening our knowledge about the factors that influence these competition processes. Cases where rival platforms compete for market share have received increasing attention. Examples include the classic battle between VHS and Betamax (Cusumano et al., 1992), Microsoft and Sun Microsystems (Garud et al., 2002) and more recently between Blu-ray and HD DVD (Gallagher, 2012).

There are three trends worth paying attention to. First, an increasing number of factors influence platform competition outcomes (Van de Kaa et al., 2011). Studying their influence on platform dominance, and accounting for their timing and delays is more difficult (Dew and Read, 2007; Cenamor et al., 2013). Ultimately, this increases the difficulty in providing insights on managerial trade-offs (Schilling, 2002). Second, empirical evidence indicates that the duration of platform competition processes historically seems to be getting shorter (Van den Bulte, 2000). This suggests that the intermediary delays between factor effects and market outcomes are getting shorter and can generate red queen effect (Barnett and Hansen, 1996; Derfus et al., 2008). Furthermore, delays in product development processes differ geographically (Clark and Fujimoto, 1991).

Third, competition processes involve macro and micro level factors (Suarez, 2004) and have grown more complex due to industry convergence (Hacklin et al., 2013; Kim et al., 2015). The result is that potentially a wider range of markets are impacted from the launch of new platforms and the outcomes of their competition. These three trends suggest that existing frameworks in the literature for studying such processes need to be re-evaluated in light of new cases of platform competition (Hill, 1997; Shapiro and Varian, 1999; Schilling, 1998, 2002; Suarez, 2004; Gawer, 2014).

There are also three theoretical developments worth paying attention to: (i) two-sided markets research (Eisenmannet al., 2006; Rochet and Tirole, 2003; 2006), (ii) ecosystem innovation research linking industry platforms to innovation management within and beyond the firm level (Gawer and Cusumano, 2014; Iansiti and Levien, 2004; Moore, 1996; Katz and Shapiro, 1994), and (iii) research on the role that macro level environmental dynamics play in platform competition processes (Suarez and Lanzolla, 2007; Tiwana et al., 2010). These point to a change in the unit of analysis in two ways: a lateral broadening of its boundary at the organizational level (point (i)), and its expansion to include multi-level factors reflecting market, technology and institutional environment conditions (points (ii) and (iii)). The three theoretical developments point towards multi-level theorization of platform competition and the need to refine the existing theoretical frameworks. The implication of the trends and theoretical developments taken together is that there are potentially more managerial trade-offs to be addressed.

The complexity, timing and delay issues that the trends pose are significant challenges for platform research that may be addressed through modelling and simulation (Davis et al., 2007; Harrison et al., 2007). There is already a wealth of modelling and simulation work upon which to begin (Rochet and Tirole, 2003; 2006; Caillaud and Jullien, 2003; Windrum, 2004; Parker and Van Alstyne, 2005; Armstrong, 2006; Ohori and Takahashi, 2010; Casey and Toyli, 2012; Hagiu and Spulber, 2014; Hagiu and Wright, 2015).

However, these simulation studies have not informed the existing theoretical frameworks about the role of delays in platform competition. Moreover, the potential that modelling and simulation has to offer has not been taken up in relatively recent articles outlining future research directions (Tiwana et al., 2010; Narayanan and Chen, 2012; Gawer and Cusumano, 2014). While Tiwana et al. (2010) explicitly refer to the need to complement platform competition analyses with dynamic, temporally dependent variables (e.g. evolution rate, mutation, survival/mortality), they stop short of stating how these variables could be implemented with modelling and simulation to answer relevant research questions. Furthermore, they consider the supply side of platforms only.

The development of middle-range theories (Hitt et al., 1994; Merton, 1968) is proposed as a way forward by Narayanan and Chen (2012) and Tiwana et al., (2010) in order to develop the kind of integrative research that will address the research areas they outline.

Middle-range theories are empirically grounded, but are neither as grand in scope as overarching theories of science and technology nor as specific as empirical observations. They provide a satisficing trade-off between the criteria of good theory: accuracy, generality and parsimony (Weick 1989; Whetten, 1989). Nevertheless, this proposal doesn't consider the potential of modelling and simulation methods for developing middle-range theories (Kopainsky and Luna Reyes, 2008; Miller, 2015).

This is an important gap in the literature. No systematic argument for using such methods for platform competition has been put forward. No research agenda outlines particular research questions that utilize the potential that modelling and simulation has to offer to platform competition research. This paper aims to fill this gap in the literature. It is a step towards bridging the rich qualitative case research already available at present, with deductive research, where inductive theory development from cases produces new theory, which is then deductively tested through simulation (Eisenhardt and Graebner, 2007). The underlying assumption in proposing the systematic use of modelling and simulation alongside empirical cases is that its strengths can counter the weaknesses of qualitative studies and vice versa (Jick, 1979). The two particular methods for modelling and simulation considered here are system dynamics and agent based modelling (Sterman, 2000; Epstein, 2006).

Section 2 outlines reasons for using modelling and simulation in platform competition research. Section 3 outlines the research outlook. It proposes 14 research questions and managerial trade-offs that can be fruitfully addressed with this method. For consistency, the paper follows the framework for organizational research proposed by Astley and van den Ven (1983) which is also used in Narayanan and Chen (2012). It is suitable for theories focusing on macro or micro-levels of analysis and accommodates natural selection, firm adaptation, strategic choice, and individual and collective actions perspectives on firms. Finally, sections 4 and 5 conclude the paper.

REASONS FOR USING SIMULATION IN STUDYING PLATFORM COMPETITION

The most recent conceptualisation of platforms, spanning engineering design and economics perspectives, defines platforms as (Gawer, 2014, p1245): "evolving organizations or meta-organizations that (i) federate and coordinate constitutive actors who can innovate and compete, (ii) create value by generating and harnessing economies of scope in supply or/and in demand, and (iii) entail a technological architecture that is modular and composed of a core and a periphery." A wide range of factors are thought to influence the outcome of platform market competition (Narayanan and Chen, 2012). In its simplest form, understanding platform market competition requires an explicit consideration of relevant factors and their interactions in terms of their nature (reinforcing or abating), intensity, and timing, and how these unfold over time.

This is challenging as cause and effect are often temporally separated due to system feedback, delays and accumulation processes (Sterman, 1994). *Ex-post* explanations about platform competition need to be tested to see whether the nature, intensity, and timing of factor interactions are actually the causes that generate the outcome of the competition (Epstein, 2007). This involves testing them for: (i) their internal consistency, (ii) whether the proposed factor interactions can generate the documented competition outcomes, and (iii) whether alternative explanations provide a better explanation of the competition outcome. Moreover, *ex-post* explanations of competition cases have a limited usefulness and utilization in management (Tushman and Anderson, 1986). A more interesting and useful theory on the

subject will offer better *ex-ante* understanding of the dynamics of platform competition (Suarez, 2004). In accomplishing this, three challenges arise owing to the changing socioeconomic context where platform competitions take place, the implications this has for defining the boundaries of such processes, and the human cognitive limitations in studying them.

First challenge: changing conditions of competition processes

Case studies have produced a number of "if condition then competition outcome" statements that draw on competition cases and/or theoretical frameworks. For example, if the installed base of a platform grows then this confers a significant advantage to it and may lead to its dominance (Suarez, 2004). Alternatively, if a penetration pricing strategy or marketing strategy is applied, such as pre-announcements of platform launches, it may lead to platform dominance. Though such statements provide valuable insights, this correlation of conditions with outcomes does not necessarily reflect causal relations (Sayer, 1992).

For example, factor interactions of equal intensity but opposing in nature may generate an outcome of apparent slow or no change, not a winner takes all outcome (Lee et al., 2006). Multiple platform systems may coexist when they have strong ties to their market bases (Cennamo and Santalo, 2013; Suarez, 2005). It is also possible that strategies designed to stimulate platform market share growth can actually lower it when implemented together with equal intensity. For example, in the US video console platform industry (Cennamo and Santalo, 2013) providers are pursuing strategies that aim to encourage competition between software game providers in order to ensure availability of high quality games for their platforms while also simultaneously pursuing exclusivity deals in order to deny these games from rivals. This can counter the positive effects of game provider competition or even discourage them from entering into a deal with a platform provider.

The converse is also possible - opposing factor interactions may be taking place but a platform may become dominant nevertheless. Network effects do not necessarily correlate linearly with the size of the installed base or the number of available platform complements (Shankar and Bayus, 2003; McIntyre and Subramaniam, 2009). This is because the marginal impact of a unit increase in network size on demand may be higher for one of the two platform bases. For example, while Sega game platforms had initially a larger installed base than Nintendo, it eventually surpassed Sega due to higher network intensity (Shankar and Bayus, 2003). Another important aspect is the temporal variation of factor intensity and how it influences platform competition. For example, as network intensity decreases the differentiation of platforms based on quality, price may become more important to consumers than network effects (McIntyre and Subramaniam, 2009).

Therefore, it is necessary to assess the nature of interactions as well as their intensity. The effect of timing of interactions on the outcome of competition is also important to the consistency of an explanation (Dew and Read, 2007). For example, assessing when market entry timing is decisive or not, for platform success. Timing becomes even more important in the introduction of successive platform generations as in the case of game consoles (Gallagher and Park, 2002). The need to consider all of the interactions and their combined effect while accounting for their nature, intensity and timing implies that an endogenous, longitudinal, systemic perspective must be taken.

The correlation of conditions with outcomes is also problematic because platform market competition has technical and social aspects whose nature is changing (Sayer, 1992).

There are two trends that provide evidence for this. First, the increase of platform competition factors from the mid-1970s to the present (van de Kaa et al., 2011), indicates that the social context and timeframes in which these take place is continuously changing and affects platform competition (Van den Bulte, 2000). While factors identified in past platform competition cases may continue to be relevant in the future, their number is likely to continue to grow in the near future as sustainability issues will become decisive (Manning et al., 2012; Boudewijn and Glasbergen, 2014).

The second trend is industry convergence. For example, the ongoing convergence of ICT related industries shifts the boundaries of platform competition (Hacklin et al., 2013; Yoffie, 1997). The classic platform war between VHS and Betamax was primarily fought in the consumer electronics industry whereas the Blu-ray vs HD DVD battle was fought in various industries including consumer electronics, movies, and gaming (Gallagher, 2012). Depending on whether convergence results in increased competition or not (Katz, 1996) a very different strategic response from firms is required (Hacklin et al., 2013).

Thus existing platform competition frameworks (e.g. Hill, 1997; Shapiro and Varian, 1999; Schilling, 1998; Suarez, 2004; Gawer, 2014) need to be refined in order to account for these trends in a critical way since the social and technological context has changed considerably and will continue to change. This implies that we continuously need to refine, develop and test the frameworks developed. The increase in factors and the change in the nature of platform competition itself, indicate the significance of boundary definition, the second challenge, in studying such processes.

Second challenge: exploring the boundary of platform competition

A judgement about the boundary of the unit of analysis is always made in modelling a system mentally or digitally i.e. including or not a range of potential causal factors given the temporal scale of the phenomenon. This is where the second challenge lies: boundary definition. It is important because all boundaries are transient given enough time, and system behaviour depends on it. It reflects the assumptions made and the particular aims and needs of analysis, rather than the systems themselves (Cilliers, 1998). Varying the assumptions about causal relationships that are not well understood implies a corresponding variation of the boundary of the unit of analysis and a range of possible candidate explanations and theories about a platform competition case.

Boundary definition lies at the core of the trade-off between the criteria of good theory: accuracy, generality and parsimony (Weick, 1989). The effectiveness of managing this research trade-off in empirically derived mental models of platform competition is reduced for two reasons. First all other things being equal, the number of factors that a researcher can simultaneously maintain and trace the outcome of competition to is smaller than that possible with a simulation model (Miller, 1956), compromising accuracy and generality. Second in examining platform competition and taking a long temporal horizon, the number of influencing factors inevitably increases i.e. the system boundary grows with the time horizon. It gradually becomes harder to distinguish the factors that are influential from those that appear to be, thus parsimony is compromised. It requires systematically adding or removing factors and/or interactions among diverse factors and among groups of stakeholders and testing their effects, in other words, system boundary exploration.

Modeling and simulation can facilitate boundary exploration. For example, boundary adequacy testing is a standard part of system dynamics methodology (Sterman, 2000). It involves searching for, and rigorously considering available empirical data in order to inform

boundary definition (Harrison et al., 2007). This process results in the removal of superfluous factors and the inclusion of influential ones only. Boundary exploration should guide the data gathering process including delays in platform competition research, an issue that has been neglected so far. Its application to platform competition studies should result in a definitive set of influential factors and thus allow research to venture beyond identifying mere similarities among cases. Most importantly it would highlight the importance and role of delays in platform competition and could potentially lead to refinements in existing theoretical frameworks.

Third challenge: overcoming cognitive limitations

The third challenge is linked to the first one. One could argue that delays involved in these interactions can be identified and their effect deduced and incorporated in theoretical frameworks - hence there is no need for modelling and simulation. However, two human cognitive limitations are related to that: the "misperception of feedback" (Sterman, 1989a; 1989b; 2008) and the "stock and flow failure" (Cronin et al., 2009). According to this research, people misperceive system delays, feedback and accumulation processes. This adds a further level of difficulty in updating the researcher's mental models about ongoing or completed platform competitions. It is inevitably a long and ineffective process due to the causal ambiguity that path dependent systems exhibit when operating far from equilibrium (Sterman, 1994).

There are two additional inherent limitations to disentangling causal ambiguity: (i) for processes that unfold over several years, a study horizon greater than the delays embedded in the system is required thus making it difficult to update mental models, and (ii) humans observe only the mode of system behaviour that actually takes place However, a wide variety of outcomes is by definition possible in path dependent processes. Tracing the evolution of a path dependent system can tell us why certain phenomena and not others finally emerged, but only identifying and testing causal mechanisms can tell us why certain phenomena and not others became possible in the first place (Goldstone, 1998).

Given these limitations, accounting for delays solely through qualitative studies is challenging because a number of important phenomena are involved in platform market competition research. These include processes of path dependency (Arthur, 1994; Garud and Karnoe, 2001), network externalities (Katz and Shapiro, 1985; 1986). Unfortunately, such processes are not easily studied analytically except from static settings or simple dynamic settings. This is illustrated in Zhu and Iansiti (2012) and Loch and Huberman (1999) where the effect of complementarities and other increasing returns to scale related factors is difficult to track analytically. Modelling and simulation allows research to go beyond the range of available analytical solutions (Oreskes et al., 1994).

Finally, modelling and simulation is not only valuable for research but also for firms directly involved in platform market competition. The existing platform competition frameworks indicate the factors that firms can influence directly from those that are beyond their control. However, research on how firms can strategically modulate network intensity (McIntyre and Subramaniam, 2009) and cope with potential interdependence, conflicts and trade-offs between the strategies they use to leverage or guide network effects has been neglected (Cennamo and Santalo, 2013). While strategies taken in isolation can be beneficial for platform performance this is not necessarily so when considered together.

The transfer of theoretical frameworks in simulation models along with an explicit appreciation of the delays involved can be used precisely to study such strategic trade-offs and offer insights to firms. The questions to which modelling and simulation can be applied are outlined in the following section.

RESEARCH OUTLOOK

Four perspectives on organizational analysis

The research outlook follows the four perspectives proposed in Astley and Van de Ven (1983) and adopted in Narayanan and Chen (2012). The research outlook of Tiwana et al. (2010) is also considered under the same perspectives. They are suitable for a future research outlook because they allow the inclusion of: (i) macro and micro levels of analysis, (ii) environmental selection, firm adaptation and strategic choice, and (iii) individual and collective actions of firms. These perspectives account for a range of assumptions regarding the capacity of organizations and organizational actors for autonomous, independent action. They also account for a range of units of analysis from the micro to macro levels. They are: system structural, strategic choice, natural selection and collective action perspective of organizations. Each of the following sections start with a brief discussion of one perspective. Then discussion develops a research agenda of 14 points for exploration with modelling and simulation.

Natural selection perspective

Perspective outline.
This perspective emphasizes the limits of autonomous strategic choice for organizations and organizational actors (Aldrich, 1979). They are seen as severely limited in their ability to adapt to different niches in their environment. This perspective takes organization populations as its unit of analysis. Organizations either fit and thrive by chance into a niche area, or are selected out by forces acting in their environments and fail (Hannan and Freeman, 1977). They survive or fail regardless of the actions taken by single organizations within them. Change is explained in terms of a natural drift of resources through the economy, rather than in terms of internal managerial action. Explanatory primacy is ascribed to the environment, which channels organizations in predetermined evolutionary trajectories. The natural selection perspective may be suitable when platform research focuses on explaining the process of platform evolution, or market level outcomes such as winner-take-all dynamics.

Research outlook.
Natural selection implies the emergence of a winner in the evolutionary competition between competing platforms in markets with increasing returns to adoption (Arthur, 1994). Three conditions are necessary for a winner take all situation (Eisenmann et al., 2006): (i) it is costly for users to adopt more than one technology, (ii) network effects are positive and strong, and (iii) users do not have strong preferences for special features. Also early market entry gives a first mover advantage (FMA) which may result in a winner take all outcome. Nevertheless, it is possible to have other outcomes as well (Lieberman and Montgomery, 1988; Katz and Shapiro, 1992; Suarez and Lanzolla, 2007; Cennamo and Santalo, 2013). For example, it may be possible that platform adoption costs may be low, allowing consumers to use several platforms and thus keeping the market in a state of intense perpetual competition.

This suggests that there is a threshold of "strength" for network effects and user preferences above which a winner takes all situation arises. It also plausible that a threshold exists in some networks beyond which the marginal benefit of adding one more member to the network becomes small (Liebowitz and Margolis, 1994). Drawing on the arguments developed in section 2, a research direction is to computationally explore the existence of this "strength" or intensity threshold in platform competition and its prerequisite conditions.

Question 1. How do the characteristics of environmental dynamics affect the likelihood of platform survival and/or dominance given a set of network effects and user preferences of particular strength?

Investigating the symmetrical issue involves looking at the platform supply side and how the endogenous attributes of an ecosystem (architecture, governance) and the dynamics of its exogenous environment, influence the evolutionary dynamics of platform ecosystems and modules (Tiwana et al., 2010). For example, a misalignment of platform governance with environmental dynamics may result in a delayed recognition of offered in new market opportunities. Similarly, a misalignment of platform architecture may result in a delayed response from the platform owner in mobilizing resources to exploit such opportunities. In contrast, a platform architecture that allows a variety of development options can allow proactive development actions that enable first mover advantage (FMA) or deny this to a competitor.

Research in these directions can show how platform owner choices are reinforced or diminished by the dynamics of the exogenous environment e.g. the pressures of converging technologies, the coexistence of multiple rival platforms, their survival and durability, and the influence of complementors and regulatory pressures. These kinds of questions focus attention on the timing of certain architectural choices, rather than whether they are appropriate. For example, platform modularization involves an upfront initial cost, leaving

open questions of timing and how much modularity is appropriate in an ecosystem, or when platform architecture and governance should change as the environmental dynamics change to steer it towards a more desirable evolutionary trajectory.

Question 2. How do the characteristics of environmental dynamics affect the likelihood of platform survival and/or dominance given a set of platform architecture and governance choices?

System structural perspective

Perspective outline.

The system structural perspective originates in contingency theories of organization, which link environment, firm characteristics and firm performance (Astley and Van den Ven, 1983). In this perspective, organizational behaviour is shaped by impersonal mechanisms that act as external constraints on actors. This perspective portrays the firm as a constrained system that must constantly adapt to develop a fit with its environment. Thus, the basic components of structure are roles not individuals. Structural elements are assumed to be interrelated in such a way that they serve the achievement of organizational goals and are therefore functional (Silverman, 1970). They predefine the set of behavioural expectations, duties, and responsibilities associated with a given position.

Individuals are immersed in an interdependent structure of roles that shapes and determines their behaviour. The manager's role under this perspective is to perceive, process, and respond to a changing environment by rearranging internal organizational structure to ensure organizational effectiveness and survival. In this perspective, organizational change is a form of adaptation to exogenous shifts in the environment. If platform research focuses on complementor firms then this perspective is more appropriate.

Research outlook.

Two questions arise in this perspective (Narayanan and Chen, 2012): (i) how can the firm react to technological change and the emergence of a technology platform, and (ii) what are the performance implications of the firm's adaptive strategy. The probability of survival tends to be higher for firms entering the industry before the emergence of a platform than for firms entering after it (Suarez and Utterback, 1995). In the personal computer market survival depends not only on firm's time of entry but also on their flexibility of technology choice (Tegarden et al., 1999). Christensen, Suarez, and Utterback (1998) found that when dominant platform designs emerged in the hard disk drive industry, firm survival had more to do with the entry window rather than FMA. A first step here would be to look across cases in this literature for candidate factors and demonstrate they are indeed important, or not, through modelling and simulation.

The window of opportunity is an outcome of environmental dynamics and Tiwana et al. (2010) consider three. First, the technological trajectories, which include the pace, unevenness, scope and unpredictability with which complementary and substitute technologies can emerge and affect their evolution. Second, the multi-homing cost i.e. the complementor costs for associating with more than one platform. With high multi-homing cost, complementors need a good reason to associate with multiple platforms (Eisenmann et al., 2006). As competing platforms lower their multi homing costs they compete for attracting complementors and increasing their chances to succeed.

An interesting trade-off arises here between platform owners and developers of platform modules and complementary products as their interests potentially diverge. Complementors hedge against their early market entry risk of being locked out (Schilling, 2002) by being affiliated with several platform owners but this may lower the latter's competitive advantage. Platform owners need to have several complementors in exclusive alliances, maintain a powerful bargaining position to them, and encourage competition between them in order to provide a more complete and competitive final platform offering. This increases the complementors risk. Moreover, as competing platforms lower multi homing costs for module developers, rival platforms can begin to pull developers away from the focal platform and thus dilute any FMA they might have. Exploring such issues requires considering at least two platform groups competing simultaneously, and the application of modelling and simulation to overcome the complexity of the situation.

Question 3. How do multi-homing costs and the pursuit of market share drive the coevolution of collaboration choices among platform owners and complementors?

The third environmental dynamic is the power of complementors that provide services to one or more platforms but are not part of the module developer community. Examples include service suppliers (e.g. AT&T supplies network bandwidth to Apple's iPhone, Warner Brothers supplies movie content to Netflix) and regulatory agencies (e.g. the Federal Trade Commission and the Federal Communications Commission).

A fourth environmental dynamic needs to be added to the first three, namely the pace of market evolution (Suarez and Lanzolla, 2007). It influences the effectiveness of competition factors that generate first move advantage (FMA). For example, the ability of a firm to pre-empt scarce market resources depends on the pace at which an industry is growing. High market growth implies that there will always be enough resources for new entrants (Pfeffer and Salancik, 1978; Dess and Beard, 1984), in effect diluting any first mover advantage a firm might have (Suarez and Lanzolla, 2007).

Future research could look at how combinations of all four environmental dynamics reinforce or dilute FMA factors. A range of different timing scenarios should be explored. This results in a combinatorial increase in the number of possibilities to consider, and requires taking a simulation approach. A further realistic direction is that convergence of disparate technologies may allow continuous growth of markets and technology changing in effect the shape of S-curves. In this case the assumptions and propositions of Suarez and Lanzolla (2007) may not hold at all.

Question 4. Investigate the combined effect of four environmental dynamics and their timing on the outcome of platform competition.

The FMA that environmental dynamics enable is also related to the intensity of the network effects that a platform can enjoy (Bayus and Shankar, 2003; Cennamo and Santalo, 2013). This is something not discussed in Suarez and Lanzolla (2007). For example, a smooth S-curve for environmental factors and network effects of low intensity, may not confer a substantial FMA to a platform. Conversely, it is possible that high intensity network effects may overcome the diluting effect of abrupt S-curve environmental factors. This needs to be tested by appropriately modelling and simulating the market dynamics that arise in such situations.

Question 5. Under which conditions is it possible for network effects to overcome the diluting effect of environmental factors on FMA?

Strategic choice perspective

Perspective outline.
In the strategic choice perspective firms are socially constructed entities, they are embodiments of individual action. Actors have choice and autonomy in the design of organizational structure and its environment does not constitute a set of obdurate constraints. It can be changed and manipulated through political negotiation to fit the objectives of management (Pfeffer and Salancik, 1978; Lorange, 1980). Managers are seen as performing a proactive role for micro and macro level change (Astley and Van de Ven, 1983). Their choices are perceived as autonomous, and their acts as energizing forces that shape the organizational world. This perspective is more appropriate in studying how a firm may strategically move to establish a platform.

Research outlook.
The core logic of the strategic choice perspective is that firm strategic actions initiate technological change and lead to platform emergence in the industry. This may be driven by three firm level factors (Narayana and Chen, 2012): (i) institutional entrepreneurship, (ii) firm strategies, and (iii) firm resources. Firms acting like institutional entrepreneurs, compete to develop a collaborative firm network for providing critical products and/or services to the success of the platform establish. They must facilitate institutional arrangements such as regulating systems and resources allocation, and initiate or participate in the political and collective processes through which platforms emerge and become legitimate.

Firm strategies include: (i) platform bundling and compatibility strategies, (ii) learning and innovation, and (iii) proprietary vs open platforms. Compatibility induces users to converge around a single platform rather than support multiple ones. This may result in platform dominance over time but pursuing compatibility may not be the best strategy (Schilling, 2002; Farrell and Saloner, 1986). Furthermore, making a platform compatible with previous generations increases its chances of achieving or maintaining dominance (Lee et al., 2006) as it can make use of the previous installed base of the platform.

Question 6. Investigate the trade-off between intergenerational platform compatibility versus the technological constrains it imposes in competitive environments at varying technology learning rates.

Learning and innovation is also important as the firm offering an overall better platform than its competitors is more likely to become dominant (Suarez, 2004; Schilling, 2002). Achieving a high rate of learning requires that firms controlling complex systems must have the required absorptive capacity to integrate external knowledge and apply it (Cohen and Levinthal, 1990). Late entrant firms must learn at a faster pace in order to improve their platform offerings and overcome their initial disadvantage compared to market incumbents. The amount of firm learning possible relates to conditions and factors of the domain it operates (van den Bosch et al., 1999). Hence, a concomitant question is how does the probability of success depend on the number of competitors already existing in the market. In order to answer this, a simulation model could be used that would allow varying the number of platform competitors and learning rates.

Question 7. Investigate the role of absorptive capacity, environmental learning effects and number of competitors in platform competition outcomes.

Disadvantages late entrants may suffer relate to low critical firm resources such as complementary products and installed base (Suarez, 2004; Schilling, 2002). Thus, the timing of complementary product market launch and rate of resource accumulation is critical for platform success. Modelling and simulation can be used to determine its relation with the likelihood of market lock-out (Schilling, 1998; Stremersch et al., 2007).

Adopting a relational view of strategy, management choices and actions should be understood from a network perspective that looks on a platform owner's relations with complementors, or other firms providing related products (Gulati et al., 2000; Dyer and Singh, 1998). Survival of competition from a complementor's perspective differs because they are engaged in a quasi-competitive situation. They may cooperate with competing platforms, and compete with complementors of the same platform. The best strategies for complementors won't necessarily align with platform owner strategies designed for market dominance. This is an interesting coopetitive situation (Ketchen et al., 2007; Branderburg and Nalebuff, 1997). The success of complementors depends not only on their actions and timing but also on the success of platform leaders and on their strategies.

Platform complementors need to hedge against such risks. They strive to associate their products with the most popular platforms (Venkatraman and Lee, 2004). The potential technological dominance of a platform supporting group and the increasingly important role of network effects in this competition, due to interconnectivity and complementary products, require managers to design their interactions with various complementors and other platform supporting actors. For example, it may be possible that platform complementors shift the balance of power with platform owners as their market offerings gain market demand.

Question 8. Investigate the implications of coopetition for survival from a platform owner and a complementor perspective.

When platform development begins, often irreversible architectural choices must accommodate unforeseen supply and demand changes. Inevitably, they influence the evolutionary dynamics of platforms and their modules (Tiwana et al., 2010). An ideal architecture should support variety in the present and evolvability over time (Baldwin and Woodard, 2009). In this respect, three properties of platform architecture are relevant (Tiwana et al., 2010; Dhanasai and Parkhe, 2006): decomposition, modularity and design rules of platform architecture.

Decomposition is the way the platform functions are broken down into low-level subsystems. Modularity refers to the degree to which changes within a subsystem do not influence the functionality of other platform subsystems (Baldwin and Woodard, 2009). Decomposition minimizes interdependence among the evolution processes of platform components, and supports change and variation. However, it comes at an upfront design cost and can also irreversibly constrain or overly expand the scope of ecosystem components.

An untested proposition is that modularity decreases coordination costs and transaction costs across module boundaries, and thus it decreases the delay in launching platform updates (Baldwin, 2008). Increasing modularity frees up platform developers to focus on more challenging problems, it makes interfirm ignorance a valuable resource (Tiwana, 2008; Barney and Clark, 2007), and encourages even greater specialization that drives development of differentiated capabilities among platform subsystems. However, modularity can also enable imitation that may erode the distinctiveness of modules and platforms and narrow the scope of learning by platform owners (Pil and Cohen, 2006; Schilling, 2000).

A trade-off arises here for managers: increasing modularity in order to decrease coordination costs and allow adaptation versus avoiding platform imitation and inviting unwanted competition. A trade-off point may exist beyond which the benefits of modularization are outweighed by the threat of competitive imitation (Figure 1). There is already modelling work done on imitation of firm strategies (Rivkin, 2000), modularity and innovation (Ethiraj and Levinthal, 2004), and a similar approach can be adapted to the combined effect of modularization and imitation of platform modules.

Question 9. Investigate the threshold beyond which the threat of imitation outweighs the benefits of platform modularization.

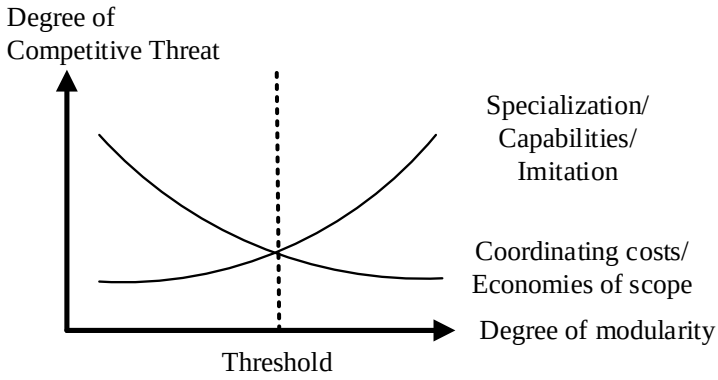

Figure 1 Managerial trade-off for modularity.

Finally, platform design rules concern both platform designers and complementors and relate to whether a platform is open or proprietary (Narayanan and Chen, 2012). Platform stability and versatility over time are critical properties of design rules (Baldwin and Woodard, 2009). Stability ensures that module and complementary product developers can join the platform group at different times. However, it also means that the platform design cannot adapt promptly over time. Platform owners face a trade-off of how to make design rules stable so that developers can commit to the platform yet versatile enough to allow for precisely the kind of proactive action that is required to ensure survival in the evolutionary platform race.

The trade-off between design rule stability and change has two parts. First, whether and when to grant platform rights in order to stimulate complementary innovations and open new markets (Boudreau, 2010). The degree of openness may vary substantially ranging from purely proprietary to completely open, and is mainly reflected in the platform licensing policy (Suarez, 2004). An open architecture strategy may significantly reduce network related entry thresholds and stimulate cooperative input to advance the technological offering of a platform. Thus, it might result in wider platform adoption and increased profitability. However, it can also introduce intra-platform competition and result in poor appropriability, eroding the competitive advantage of platform setting firms and reducing the platform owner share of profits (West, 2003).

The temporal aspect of this trade-off lies in that the number of licensed producers directly influences the time it takes to release a new version of a platform (Boudreau, 2012). The degree of openness may need to vary during a platform competition in order to respond or pre-empt competitor moves. An issue that can explicitly be addressed through modelling and simulation is the timing and the benefits of switching from open to proprietary or vice versa.

Question 10. How does the timing and level of platform access affect platform profits, scale and speed of adoption?

The second part of the trade-off lies in allowing access to the platform technology to attract and benefit from the input of outside innovators. Opening the platform to outside contribution creates a new challenge i.e. accumulating and controlling diverse contributions to a single artefact (Dhanasai and Parkhe, 2006; Thomas et al., 2014). The variety of complements grows in correlation with the number and heterogeneity of complementors. It is logical to anticipate a threshold beyond which unfettered growth can also produce low-quality results and complements, resulting in negative customer experience and risk for the reputation

and economic viability of the platform (Boudreau, 2012). It may well be that a main growth constraint is the degree of complementor heterogeneity that the governance of a single platform ecosystem can sustain.

This stability-evolvability trade-off manifests in the platform development and the actors and their interests (Dhanasai and Parkhe, 2006; Wareham et al., 2014). The trade-off lies in restraining the breadth and innovativeness of the complements versus permitting unrestricted growth in inferior quality complements and inferior service levels. Excessively strict governance could suffocate entrepreneurial responses to client needs, whereas excessively open governance could permit the uncontrolled diffusion of poor business practices. Although this implies that some balance is desirable, extreme positions may suit technology ecosystems at different stages of platform maturity (Wareham et al., 2014).

Question 11. How does the increasing the number of platform complementors affects the competitiveness of the platform on its viability.

Accounting for timing of all strategic action, not just market entry timing (Suarez, 2004) is a distinct research direction altogether. Delays arise in firm strategies for customer retention. Platform launch decisions depend on the role of early adopters in the diffusion process (Frattini et al., 2014). Firms use launch decisions to leverage early adopters. Early adopters influence the adoption process by disseminating information about platforms and triggering imitative behavior. In doing so they can reduce the delay in critical mass build up and thus be the stepping stone for a broader diffusion. This can lead to rapid but risky growth path for a platform due to their frequent switching behaviour. In contrast, emphasizing the core platform value, engaging customers with defensive marketing, increasing platform complexity, introducing loyalty programs and encouraging broader use should lead to slower, sustainable growth.

A related issue is the effect of switching costs and their timing on customer acquisition. If customers perceive high switching costs between competing platforms that could potentially lock them in for some time, then they may delay choice and adopt a wait and see strategy. Raising switching costs early to retain existing customers may result in low customer acquisition rate especially of new, inexperienced users, precisely the market segment with the greater retention potential. Nevertheless, it may secure the existing platform customer base. Thus an interesting strategic issue is the trade-off between switching costs, customer acquisition and the timing of changing switching costs when shifting focus from customer acquisition to retention.

Question 12. Investigate the timing of platform switching costs decisions in building short-term critical mass of early adopters versus building long-term sustainable customer base.

Collective action perspective

Perspective outline.

The collective action perspective views organizations as being guided by collective purpose and choice, rather than being engaged in competition for survival through a direct confrontation with the natural, or exogenous environment. Firms may act collectively to achieve shared strategic purposes. Therefore, the focus is on how the collective action of population of firms can generate change in the industry. The perspective emphasizes collective organizational survival, achieved through the construction of a regulated and

controlled social environment that mediates the effects of the external environment (Ackoff, 1974; Schon, 1971). The key concept here is the interorganizational network of symbiotically interdependent, yet semiautonomous organizations that interact to construct or modify their collective environment working rules and options.

Research outlook.

From a collective action perspective, platform competition is a dialectical process where actor coalitions engage in competition to create and establish platforms (Hargrave and Van den Ven, 2006). It is supported by a co-specializing network of complementary actors collectively possessing the skills and resources required for its development (Cusumano and Gawer, 2002; Murmann and Frenken, 2006; Thomas et al., 2014). In dynamic market settings the function of these networks is in providing quick access to new knowledge and thus enabling first-mover advantage (Grant, 1996) The platform owner controlling the core technology faces two challenges: (i) competition with competing platforms and (ii) the coordination of complementary products suppliers (Annabelle and Cusumano, 2002; Cusumano and Gawer, 2002).

The drivers of collective action in platform competition are (Narayanan and Chen, 2012): (i) platform complexity, (ii) forms of regulatory action, and (iii) firm motives. Facilitating platform development into a complex technological system requires collective efforts from various actors, internal and external innovation units, the suppliers of core and periphery components, technology users, and other actors like the government and industrial societies (Lee and Lim, 2001). For example, Cottrell (1994) points to the differences between Japanese and US policies for addressing short and long-term problems in their respective software industries. While Japanese firms lagged in the short term, facing challenges associated with multiple platforms, these facilitated the long-term adaptability and performance of the Japanese industry. In contrast, the US industry benefited from a single dominant platform but has experienced difficulty moving to new ones. Studying policies in collective action settings is even more relevant as the need for sustainable technological solutions in a number of sectors requires both adaptability and performance.

Question 13. Investigate policies for facilitating long-term adaptability and performance of industry through platform variety vs achieving short-term benefits of reduced variety.

Empirical work has also explored firm motives for engaging in collective action, for example by examining the role of institutional entrepreneurs in initiating collective action of complementor firms whose technology co-evolves with the core platform technology (Garud et al., 2002; Hargrave and Van de Ven, 2006). Firm motives to participate in such collective action may depend on their technological capability (Blind and Thumm, 2004), absorptive capacity (Cohen and Levinthal, 1990) and the amount of environmental uncertainty (Kogut et al., 1995). For example, as a technology market matures, uncertainty reduces and the interaction between firms changes from collective efforts to legitimate it, to differentiation and competition (Navis and Glynn, 2010). This immediately introduces macro level considerations requiring a long-term view in exploring the conditions under which firms enter collective action.

Interfirm relations may take different forms of collaborations and competition (Murmann and Frenken, 2006). As the number of firms in a platform group increases toward a critical mass, a mixture of cooperative and competitive relations develops. It is the collective action of this emerging network, composed of “institutional entrepreneurs” (Garud et al., 2002) and peripheral firms that eventually will transform into a commercially viable industry (Hargrave and Van de Ven, 2006).

Cooperation and competition among platform groups often has a hierarchical structure (Van de Ven et al., 1999; Dhanasai and Parkhe, 2006). On top is the competition between technological leaders and platform owners. In the early stage of platform development, fierce competition may occur and firms within a group must cooperate to keep competitors from creating new institutions in the industry (Garud et al., 2002; Hargrave and Van de Ven, 2006). In later stages, even firms from competing platform groups may collaborate. For example, in the personal computer industry there have been a number of alliances between the dominant Wintel platforms and Apple. It appears that the timing of cooperation between technological leaders is critical. Partnerships between the two competing platforms, took place only after Wintel became dominant (Hagedoorn et al., 2001).

Question 14. How does the mixture of competitive and collaborative action evolve with the number of firms engaged in a platform development group and with macro level conditions?

RECOMMENDATIONS FOR DESIGNING STUDIES

The 14 points of the research outlook and the questions of platform market launch timing and preannouncement point to a particular array of theoretical constructs that future models on platform competition should include (Figure 3). They are listed in four groups reflecting the four broad themes explored in the research outlook: platform ecosystem issues, market conditions, timing, and macro level-environmental conditions.

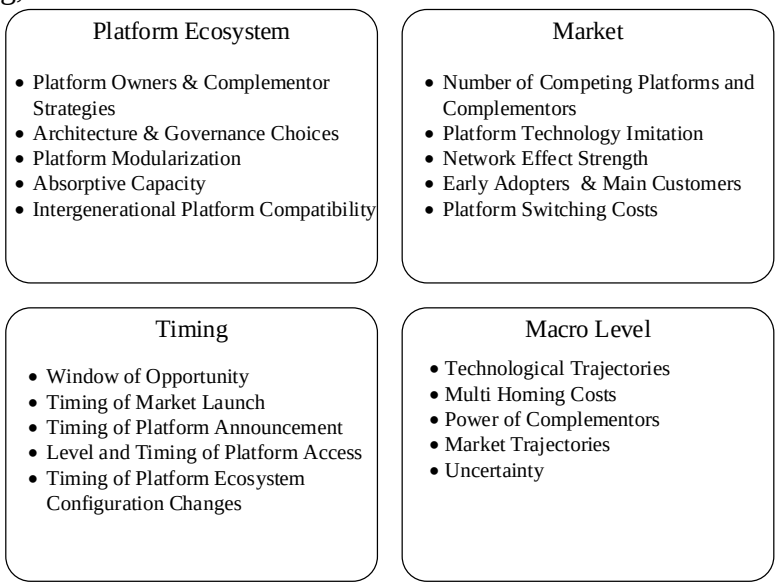

Figure 2 Grouping of simulation related issues

The use of modelling and simulation allows the exploration of non-linear and threshold effects. It is conducive to development of middle range theories. It compels the researchers to be explicit about the unit of analysis and underlying assumptions. It allows for the utilization of rich longitudinal data available for software platforms in particular. Inevitably, the application of modelling and simulation will bring about the need to find more accurate variables to represent theoretical constructs. Most importantly though the research outline in this paper is a step towards bridging the rich qualitative case research already available at present, with deductive research, where inductive theory development from cases produces

new theory, which is then deductively tested through simulation (Eisenhardt and Graebner, 2007).

Several potential contributions from undertaking the outlined research in this paper arise. From a natural selection perspective it can be an understanding of the environmental conditions that are conducive to entering and surviving in a platform market and the initial conditions that platform group members must fulfil to fit into particular market niches. From a system structural perspective, it can be insights into developing the appropriate capabilities to respond to complementor actions (from a platform owner perspective) or platform owner actions (from a complementor perspective). Additional insights include responding to environmental dynamics reinforcing or diluting effect on advantages of the platform. From a strategic choice perspective, insights about increasing the platform development capability, and insights relating to relation to platform complementors and the timing of related actions. From a collective action perspective, insights about appropriate configurations that facilitate short term benefits and long term adaptability of the platform development group

CONCLUSIONS

Over the past decades a variety of perspectives and methods have been used for platform competition research. This research note discusses reasons why modelling and simulation should be systematically used and explores research directions it opens up. Qualitative research may be sufficient for identifying factor interactions and characterising their nature as reinforcing or disrupting, but not for evaluating the effect of their intensity and timing which are directly linked to a number of platform competition questions and managerial trade-offs. It is important to explicitly consider intensity and timing because empirical evidence suggests that the duration of platform competition processes historically seems to be getting smaller which suggests that delays in factor interactions that directly influence their outcome are changing. In addition, platform market competition processes have grown more complex because industries are converging (Hacklin et al., 2013). The result is that the market outcome of platform competition is influenced by and has an impact on a wider range of markets. In order to cope with complexity, the study of such processes should go beyond the use of analytic methods.

This is where there is a gap as existing frameworks (Hill, 1997; Shapiro and Varian, 1999; Schilling, 1998, 2002; Suarez, 2004; Gawer, 2014) are not equipped to account for these characteristics. Recent research outlines have not taken into account the potential of modelling and simulation in setting a future research agenda. In response to this, the paper outlined seventeen future research directions from four different perspectives on organizational theory where modelling and simulation can contribute.

The future research outlined here aims explicitly at the timing and delays involved in platform competition processes and provide an answer to the call for integrative research involving micro and macro level issues, endogenous and exogenous factors and explicit consideration of platform owners and platform complementors. The hope is that research outcomes from modelling and simulation studies will feedback into theoretical frameworks and thus will keep them contemporary and relevant. As this entails the incorporation of various insights from multiple disciplines, platform competition as such will become more complex and this is where the value of modelling and simulation lies. The objective in this research commentary was to provide a starting point for research work that will realize this value.

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