Abstract

Platform competition shapes and is shaped by a constantly changing socioeconomic context. Three trends provide evidence for this: (i) the number of firm level relevant factors for platform success is steadily increasing, (ii) contemporary cases of platform competition take less time to unfold, and (iii) industries converge. These trends suggest that there is a change: in the time required for relevant factors to influence platform competition, and in the trade-offs managers face when they take actions in platform development and competition, to influence the market outcome of such processes. Current frameworks in the literature do not account explicitly for such timing issues. The use of modelling and simulation, along empirical cases, is a way to incorporate timing and strategic action delays in platform competition research. We explore the multi-level research agenda this opens up and develop nine research questions for platform competition research.

Keywords: simulation, platforms, competition, technology management

1. Introduction

Platform-based markets are highly important in several industries and the number of platforms, and firms involved in their development continuously grows (Eisenman, Parker, and Van Alstyne, 2011; Zhu and Iansiti, 2012; Gawer, 2014). Platforms are essential to the operation of most technological systems, such as ICT networks, because they interconnect technological components and subsystems. The importance of platforms has generated considerable interest in platform competition processes and a lot of classic cases e.g. VHS and Betamax (Cusumano, Mylonadis, and Rosenbloom, 1992), Microsoft and Sun Microsystems (Garud, Jain, and Kumaraswamy, 2002), and more recently Blu-ray and HD DVD (Gallagher, 2012).

This article considers three empirical and three theoretical trends that raise issues of complexity, timing and longitudinal research design in platform research. The trends point to changes in the socioeconomic context and the need to continuously re-examine and refine current platform competition frameworks. This is an important challenge that may be addressed through modelling and simulation (Davis, Eisenhardt, and Bingham, 2007; Harrison et al., 2007), that has been applied to platform research (Parker and Van Alstyne, 2005; Zhu and Iansiti, 2012; Papachristos, 2017).

However, these simulation studies have not informed current frameworks (Shapiro and Varian, 1999; Schilling, 1998, 2002; Gawer and Cusumano, 2002; Suarez, 2004; Gawer, 2014), about the role of socioeconomic context. It is important because it underlies intermediary platform competition factors, the delays in their effect, and eventual competition outcomes. A new platform may offer more private and social incentives for its adoption, but potential adopters may be committed to other platforms for various reasons e.g. compatibility. As a result, a new platform user base takes time to grow.

The inclusion of a dynamic socioeconomic context and macro level industry evolution in platform competition research requires a longitudinal research approach. The question is how to complement platform competition cases with simulation models that include dynamic, temporally dependent variables (e.g. evolution rate, survival/mortality). However, a bridge to simulation methods needs to be made. A careful reading of recent review articles that propose future research directions reveals that they do so without considering the potential of modelling and simulation methods to contribute to theory development on platform competition (McIntyre and Subramaniam, 2009; Tiwana, Konsynski, and Bush, 2010; Narayanan and Chen, 2012; McIntyre and Srinivasan, 2017).

This paper aims to address this, and provide a systematic argument for modelling and simulation use in platform competition research. The two methods considered are system dynamics and agent

based modelling and simulation (Davis et al., 2007; Harrison et al., 2007). The aim is not to suggest that either is better suited to address particular questions, or that they are better vis a vis other approaches for platform competition research, and can replace them. Each has its own merits and weaknesses. For example, several formal, theoretical models exist but they are somewhat limited in their ability to fully represent complex platform competition processes (Rochet and Tirole, 2006; Hagiu and Spulber, 2014). This is illustrated in Zhu and Iansiti (2012). Initially, they follow an analytical approach in their paper, but later they use simulation because it is difficult to ascertain otherwise the effect of complementarities and other scale related factors.

Besides simulation there are other methodological approaches to study platform competition. Each one sits along different point on the spectrum between accuracy, simplicity and generality in terms of theory development (Figure 1). The mixed use of modelling and simulation with other methods is based on the assumption that they do not share the same weaknesses or potential for bias, and that the strengths of each method counter the weaknesses of the other (Johnson et al. 2017). In this way they can offer a better trade-off between the criteria for theory development: accuracy, generality and parsimony (Weick, 1989).

Place Figure 1 Here

Section 2 begins by examining the theoretical and empirical trends that provide the underlying rationale and motivation for the argumentation for using modelling and simulation in platform competition research. Section 3 presents the research outlook with 9 research questions and managerial trade-offs that can be fruitfully addressed with simulation. Finally, sections 4 concludes the paper.

2. Reasons for using simulation in studying platform competition

The three convergent theoretical developments considered in this paper are: (i) the emergence of two-sided markets research (Eisenmann, Parker, and van Alstyne, 2006; Rochet and Tirole, 2006), (ii) the expansion of platform competition research from the firm level to innovation ecosystem level, that links industry platforms to innovation management within, and beyond the firm level (Tiwana et al., 2010; Gawer, 2014), and (iii) the research on the effect of macro level socioeconomic dynamics on platform competition processes and First Mover Advantage (Suarez and Lanzolla, 2007; Tiwana et al., 2010). These developments point to two changes in the unit of analysis: a lateral expansion of its boundary at the organizational level (point (i)), and its extension towards multi-level theorization and inclusion of multi-level factors reflecting market, technology and institutional environment conditions

(points (ii) and (iii)). The three theoretical developments highlight the need to develop further the current theoretical frameworks.

Three empirical trends are also considered. First, the rise of number of explanatory factors considered in platform competition market outcomes from the mid-1970s to the present (Van de Kaa et al., 2011). It is difficult to study their influence and account for their timing and delayed effect on platform competition (Dew and Read, 2007; Cenamor, Usero, and Fernandez, 2013). Some factors account for platform developer strategic actions, so their timing is important. Delays concern the time it takes for strategic actions to go through the chain of intermediary factors and impact platform market share. Delays increase the difficulty in providing insights on managerial trade-offs (Schilling, 2002). Second, empirical evidence indicates that platform competition duration decreases historically (Stremersch, Muller, and Peres, 2010). This suggests a change in the intermediary delays between factor effects and competition outcomes. Third, platform competition processes involve firm level (e.g. strategies, complementary assets) and macro level factors (e.g. network effects) and have grown more complex due to industry convergence (Kim et al., 2015). The result is that platforms launches and competition outcomes impact potentially a wider range of markets (Gallagher, 2012). These three trends suggest that research on cases of platform dominance should use current frameworks with caution or revise them.

The six trends are important to understand platform competition. This requires an appropriate unit of analysis and considering all relevant factors, their interactions in terms of their: nature (reinforcing or abating), intensity, timing, and evolution through time in a changing socioeconomic context. This is difficult as humans face cognitive limitations in understanding processes where cause and effect are often separated temporally due to system feedback, delays and accumulation processes (Sterman, 1994). Thus, *ex-post* explanations about platform competition need to be tested through simulation to see: (i) whether explanations are internally, temporally and causally consistent, (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.

A more interesting and useful theory on the subject will offer a better *ex-ante* understanding of how the dynamics of platform competition may unfold (Suarez, 2004). To accomplish this, three challenges arise due to the changing context of platform competition processes, the implications this has for the boundaries of platform competition, and the human cognitive limitations involved in their study. The way modelling and simulation can address them is discussed next.

2.1. First Challenge: Changing Conditions of Platform Competition Processes

Platform competition case studies have produced a number of "if condition then competition outcome" statements. For example, *if* the installed base of a platform grows *then* this confers a significant advantage and may lead to platform dominance (Suarez, 2004). Though such statements provide valuable insights, relating conditions with outcomes does not necessarily reflect causal relations (Sayer, 1992). Platform performance in the marketplace arises out of complementary or opposing influence of factors-strategies from early and late entrants, market evolution, consumer preferences, technological and socioeconomic changes, and governmental actions (Lieberman and Montgomery, 2013).

Due to this multiplicity, manager strategies to increase platform market share, can actually lower it when implemented together with equal intensity. For example, in the US game console industry platform providers pursue strategies that encourage competition and innovation between software providers to secure availability of high quality games for their platforms. They simultaneously pursue exclusivity deals in order to deny these games from rivals (Cennamo and Santaló, 2013). This can counter the positive effects of software provider competition or even lead to crowd out effects due to excessive competition (Boudreau, 2012).

Opposing strategies of equal intensity may generate an apparent slow or no change, where multiple platforms coexist due to strong ties to their market bases (Cennamo and Santaló, 2013). Conversely, a platform may become dominant even with opposing strategies because of particular competition factors. For example, Sega game platforms initially had a larger installed base than Nintendo, but it eventually surpassed Sega due to higher network intensity. Therefore, it is necessary to assess the nature and intensity of factors and their interactions.

Another important aspect is the temporal variation of factor intensity and influence on platform competition. For example, platform quality and price become more important to consumers than network effects as their intensity decreases (McIntyre and Subramaniam, 2009). The effect of factors on competition outcomes depends on strategic action timing and it is important to the consistency of an explanation (Dew and Read, 2007). The correlation of conditions with outcomes is also problematic because the technical and socioeconomic context of platform competition changes constantly. The number of influential competition factors increases and is likely to grow more as sustainability standards will become decisive, such as fair labor and ethical sourcing of rare metals. Hence, it is necessary to consider all factor interactions, their nature, intensity and timing, and their combined effect from an endogenous, longitudinal, systemic perspective.

Moreover, platform competition boundaries shift due to industry convergence (Kim et al., 2015). 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 consumer electronics, movies, and gaming industries (Gallagher, 2012). Convergence requires a re-evaluation and refinement of frameworks as different strategic firm responses may be required, contingent on whether industry convergence results in increased competition or not (Kim et al., 2015). The increase in the number of factors and the change in the nature of platform competition, indicate the significance of the second challenge, boundary definition, in platform competition research.

2.2. Second challenge: exploring the boundary of platform competition

Boundary definition lies at the core of the research trade-off between the criteria of good theory: accuracy, generality and parsimony (Weick, 1989) because system behaviour depends on it. It reflects the assumptions made and the aims and needs of the analysis, rather than the systems themselves. The variation of causal relation assumptions requires a variation of the boundary of the unit of analysis and a range of possible candidate explanations and theories about a platform competition case.

Two challenges arise in this: (i) accuracy and generality is compromised because the number of factors that a researcher can consider simultaneously and trace competition outcomes to, is smaller than that possible with a simulation model, and (ii) parsimony is compromised because the number of influential platform competition factors grows as the system boundary grows with the temporal horizon. It gradually becomes harder to distinguish the factors that are influential from those that are not. This requires the systematic addition or removal of factors and/or factor interactions, and among groups of stakeholders, and testing their explanatory power.

Modeling and simulation can facilitate the search and rigorous consideration of available empirical data to inform boundary exploration (Harrison et al., 2007). Boundary exploration can guide data collection on platform competition delays, an issue that has been neglected so far. It can highlight the importance and role of delays in platform competition and lead potentially to refinements in current theoretical frameworks. Boundary exploration can result in a definitive set of influential factors and thus allow research to venture beyond the mere identification of similarities among cases.

2.3. Third challenge: overcoming cognitive limitations

The third challenge links to the first one. One could argue that there is no need for modelling and simulation. The interactions, feedbacks and delays between platform competition factors can be identified and their effects deduced and incorporated in theoretical frameworks. However, two human cognitive limitations make this difficult: the “misperception of feedback” (Sterman, 1989) and the

"stock and flow failure" (Cronin, Gonzalez, and Sterman, 2009). According to this research, people misperceive system delays, and feedback in path dependent processes. Platform competition involves processes of path dependency (Suarez, 2004), and network externalities (Katz and Shapiro, 1992) that make understanding platform competition, a difficult, long process due to the causal ambiguity involved (Sterman, 1994).

Two additional limitations are related to this: (i) processes that unfold over several years, require a study horizon that is greater than the delays embedded in the system, thus making it difficult to update researcher mental models, and (ii) humans observe only the competition outcome that takes place, while a range of competition outcomes is possible in path dependent processes. Tracing the evolution of a path dependent process can reveal why certain outcomes and not others emerged, but only identifying and testing causal mechanisms can reveal why certain outcomes and not others became possible in the first place (Goldstone, 1998).

Given these four limitations, platform competition research is considerably difficult except from static settings or simple dynamic settings where a small number of factors are taken into account simultaneously. This is illustrated in Zhu and Iansiti (2012) where the authors resort to modelling and simulation because it is difficult to track analytically the effect of complementarities and other increasing returns to scale related factors. The questions to which such modelling and simulation can be applied are outlined in the following section.

3. Research outlook

3.1. Four perspectives on organizational analysis

The research outlook starts from the premise that platform developers, complementors and related firms are organizations embedded in a social context and their study requires an organizational science perspective. Four organizational perspectives are followed (Astley and Van de Ven, 1983): natural selection, system structural, strategic choice, and collective action perspective of organizations They facilitate consistency and continuity with prior research (McIntyre and Subramaniam, 2009; Tiwana et al., 2010; Narayanan and Chen, 2012) and provide a broad lens for platform competition. The perspectives fit the future research outlook because they align with the theoretical developments considered and allow the inclusion of units of analysis ranging from the micro to macro level. Each of the subsequent sections discusses one perspective and develops platform competition research questions to which the modelling and simulation methodology may be applied.

3.2. Natural selection perspective

Perspective outline.

This perspective takes organizational populations as the unit of analysis. It emphasizes the limits of organizations and actors for autonomous strategic choice and adaptation to niches in their environment (Astley and Van den Ven, 1983). Organizations either fit and thrive by chance into a niche based on their foundational endowment, or are selected out by environmental forces and fail. Change is explained in terms of a natural drift of resources in the competitive environment which channels organizations in predetermined evolutionary trajectories, rather than in terms of internal managerial action. This perspective may be suitable to explain platform evolution processes, or competition outcomes such as winner-take-all dynamics.

Research outlook.

Natural selection implies the emergence of a winner in the evolutionary competition among platforms in markets that exhibit increasing returns to adoption (Eisenmann et al., 2006). However, under certain conditions other outcomes are possible as well (Lieberman and Montgomery, 1988; Suarez and Lanzolla, 2007; Cennamo and Santaló, 2013; Lieberman and Montgomery, 2013). For example, with low platform adoption costs, or weak network effects, consumers may use several platforms (multi-homing) and thus keep the market in perpetual competition. This suggests that there is a threshold of network effects "strength" and user preferences above which a winner takes all situation arises. It is plausible that in some networks a threshold exists, beyond which the marginal benefit of an additional network member becomes small. A research direction is to explore computationally the existence of such thresholds, their prerequisite conditions, and relevant market and technology dynamics discussed in Suarez and Lanzolla (2007), and Tiwana et al. (2010):

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

The associated supply side issue can be addressed through research on the evolutionary interactions of platform development, its architecture and governance with its exogenous environments dynamics (Tiwana et al., 2010). For example, a platform architecture and governance that allows for a variety of development choices which align with environmental dynamics can enable First Mover Advantage (FMA) or deny it to competitors.

Research in this direction can show how platform architecture choices on modularity, appropriability, and openness to complementors, affect platform survival and are reinforced or

diminished by environmental dynamics: the pressures of converging technologies, the coexistence of multiple rival platforms, their survival and adaptability, and the influence of complementors and regulatory pressures. For example, platform modularization involves an initial cost, that leaves open questions about the appropriate level of platform modularity in an ecosystem, or when and how platform architecture and governance should change to ensure survival.

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?

The questions from the natural selection perspective treat platform competition as a macro level phenomenon by analogy to living species (supply side), that strive for survival nature (demand side). The system structural perspective provides the lens for a closer look to platform competition.

3.3. System Structural Perspective

Perspective outline.

This perspective links environment, organizational characteristics and performance (Astley and Van den Ven, 1983). Organizational behaviour is shaped by mechanisms that act as external constraints on actors. The organization is portrayed as a constrained system that must change constantly and adapt to its exogenous environmental shifts. Structural elements are assumed to interrelate to serve the achievement of organizational goals and are therefore functional. The basic elements of organizational structure are roles, not individuals, and they predefine the set of behavioural expectations, duties, and individual responsibilities.

Research outlook.

Two questions in this perspective reflect the supply and demand sides of platform competition and firm survival: (i) how can the firm react to technological change and competition from new platforms, and (ii) what are the market performance implications of the firm's reaction. The survival probability tends to be higher when firms enter the industry in the window of opportunity before the emergence of a dominant platform when there is flexibility around technology choices rather than after it (Tegarden, Hatfield, and Echols, 1999). The window of opportunity is generated by platform competitor choices and environmental dynamics. Two socioeconomic dynamics are relevant here (Tiwana et al., 2010): (i) technological dynamics: the pace, unevenness, scope and unpredictability with which complementary and substitute technologies can emerge and affect platform evolution, and

(ii) multi-homing cost i.e. the complementor costs for associating with more than one platform (Eisenmann et al., 2006).

Complementors affiliate with several platform owners to hedge against their early entry survival risk. Platform owners need to have several complementors in exclusive alliances, and encourage competition between them to increase the competitiveness of their platform. However, this increases complementor risk. Research on these issues must consider the competition of at least two platforms where consumers can use many platforms and complementors can multi home. The next question focuses on supply side dynamics, but the related demand side question could also be explored.

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

A third, relevant socioeconomic dynamic is the market evolution pace that influences the effectiveness of competition factors that generate FMA (Suarez and Lanzolla, 2007). High market growth implies that there will always be enough resources for new entrants in effect diluting any FMA a firm might have. A fourth dynamic is consumer lifestyle changes that increase the use of new digital technologies, the concern about environmental issues and the consequent desire to purchase "green". Future research could investigate how combinations of all four dynamics reinforce or dilute FMA factors and explore a range of different timing scenarios. The convergence of disparate technologies may change the shape of these dynamics and the assumptions and propositions of Suarez and Lanzolla (2007) may not hold. Then, the effect of these dynamics on platform competition could be explored through modelling and simulation.

Question 4. How do the four socioeconomic dynamics and their timing combine to influence the window of opportunity for platform market entry and FMA?

In the system structural perspective, organizational behaviour is shaped by impersonal mechanisms that act as external constraints on managers. They can only react to exogenous, environmental shifts, and thus change is a form of adaptation. The questions developed in this section are designed to reflect this.

3.4. Strategic choice perspective

Perspective outline.

In this 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 enduring constraints. Structure and environment can be changed and

manipulated through political negotiation to fit management objectives. Managers perform a proactive role for micro and macro level change (Astley and Van de Ven, 1983). Their actions are perceived as autonomous, energizing forces that shape the organization. This perspective is more appropriate to study how a firm may strategically move to establish its platform market share.

Research outlook.

The core logic of the strategic choice perspective is that firm strategic actions initiate technological change that may lead to platforms success. This may be driven by three firm level factors (Narayana and Chen, 2012): (i) institutional network entrepreneurship, (ii) firm strategies, and (iii) firm resources. Firms strive to establish and leverage their own collaboration network to provide critical products and/or services for the success of their platform (McIntyre and Subramaniam, 2009). Management choices and actions may be understood from a platform owner or a complementor perspective (Cennamo, 2016).

From the platform owner perspective, late market entrants may suffer disadvantages due to low level of critical firm resources, complementary products and installed base (Schilling, 2002; Suarez, 2004). Modelling and simulation can be used to determine the effect of timing of complementary products market launch and rate of resource accumulation on platform market survival risk (Schilling, 1998; Stremersch et al., 2007). From the complementor perspective, market survival differs because they compete with complementors of the same platform and strive to cooperate with the most competitive platforms. Complementor success depends not only on their strategic actions and their timing but also on platform owner strategies and their success (Schilling, 2002). However, the best complementor strategies won't necessarily align with the best platform owner strategies. This tension of competing interests in a co-opetitive situation can be explored through modelling and simulation.

Question 5. How do platform owner and complementor market strategies affect the success prospects for both?

Platform architecture choices influence its development that must often accommodate unforeseen supply and demand changes. Three platform architecture properties are relevant for this (Tiwana et al., 2010): decomposition, modularity and design rules of platform architecture. Modularity refers to the degree to which changes within a subsystem do not influence the functionality of other platform subsystems. High platform modularity may decrease coordination and transaction costs across module boundaries, and thus decrease delays in platform updates and improve its competitiveness. High modularity enables platform developers to focus on more challenging problems.

However, modularity can enable competitor imitation that may erode the distinctiveness of modules and platforms and narrow the scope of learning by platform owners (Pil and Cohen, 2006). A managerial trade-off arises between high modularity to decrease coordination costs and allow adaptation, and low modularity to avoid platform imitation and increased competition. A threshold may exist beyond which the benefits of modularization are outweighed by the threat of competitive imitation (Figure 2). The threshold may be dynamic and shift during the platform lifecycle. This temporal aspect of the trade-off and the benefits of switching from open to proprietary or vice versa can be explored through modeling and simulation that will combine modularization and imitation effects based on current research.

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Question 6. How should the modularity/openess vs imitation threat trade-off be managed to improve platform adaptation and reduce competition during its lifecycle?

High access to platform technology can attract and benefit from the input of diverse, external complementors and increase the chance of platform success (Van den Ende et al., 2012). This poses a challenge of integrating these into a single platform. A high degree of platform openness and number of licensed producers may increase the time required to release a new platform generation (Boudreau, 2012). The degree of openness may also need to vary during the platform lifecycle to allow prompt responses to, or pre-empt competitors. There may be a dynamic threshold beyond which unfettered growth and complementor diversity, can result in low-quality complements, negative customer experience, and risk for platform reputation and survival (Cennamo and Santaló, 2013). Although some balance may be desirable, extreme positions may suit technology ecosystems at different stages of the platform lifecycle (Cennamo, 2016).

Question 7. How does increasing the number and diversity of platform complementors affect the stability and competitiveness of the platform during its lifecycle?

On the demand side a related issue is the effect of switching costs and their timing, on customer acquisition. Firms use platform launch decisions to leverage early adopters. Early adopters disseminate information about platforms and trigger imitative behaviour that reduces the delay in user critical mass build up. Nevertheless, it may be risky as early adopters exhibit frequent platform switching behaviour. An early rise of platform switching costs to retain customers may result in low customer acquisition

rate especially of new, inexperienced users, precisely the market segment with the greater retention potential. If this market segment perceives high switching costs between platforms, that could potentially lock them in for some time, then it adopts a wait and see strategy. An interesting strategic issue arises here on the timing of switching costs changes and shift in focus from customer acquisition to retention.

Question 8. How does the timing of decisions on platform switching costs influence the development of early adopter critical mass in the short term versus a long-term sustainable customer base?

The strategic perspective views the success and failure of a platform firm as a result of its own actions. Thus, the questions developed in this section are geared to explore the best course of action under given conditions. The collective action extends this to consider from an endogenous perspective the actions of firms that form a platform development group.

3.5. Collective action perspective

Perspective outline.

The collective action perspective views organizations as being guided by collective purpose and choice, rather than competition for survival through a direct confrontation with their exogenous environment (Astley and Van den Ven, 1983). Firms may act collectively to achieve shared strategic purposes, and survive through the construction of a regulated and controlled social environment that mediates the effects of the external environment. 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 compete to create and establish their platform ecosystems (Hargrave and Van den Ven, 2006). Platform development is supported by a network of complementary actors that face two challenges during its lifecycle: competition against other platforms, and the choice and coordination of complementary products suppliers (Cusumano and Gawer, 2002).

In the early stages of market growth, platforms need to attract users and complementors simultaneously (Katz and Shapiro, 1992). To do this it is critical to give positive signs about the platform's value and market prospects (Garud et al., 2002; Suarez, 2004). Two-sided platforms resolve

this coordination challenge by providing first-party content, often for free or as part of a product bundle, which typically increases attractiveness for consumers (Hagiu and Spulber, 2014). Initial complement availability drives the initial user base, which reinforces the attractiveness of the platform for complementors (Cennamo and Santaló, 2013).

During the later market growth stage, platform value must increase faster than competitors to retain user and complementor support. Complement availability can come from external complementors, or through in-house development (Hagiu and Spulber, 2014). High numbers of external complementors and intensified competition may reduce innovation, lower complement quality, or lead complementors to switch to new platform systems (Cennamo, 2016). Complements developed in-house, can have the same detrimental effect as complementors may worry whether they can appropriate the value of their offerings through their association with a powerful platform ecosystem (Gawer, 2014). Hence, the proportion of in-house and externally sourced complements must be balanced in each market stage.

Question 9. How does the ratio of in-house vs externally sourced complements and group of complementors need to vary in terms of quantity and quality during the platform lifecycle to sustain FMA of early platform entrants, or to cancel the FMA of competitors?

The collective perspective is the opposite of the system structural view in a sense. Organizational success is guided and constructed by collective purpose and choice instead of being subject to environmental forces and determined by evolution. This is reflected in the ninth question.

3.6. Integration across perspectives

The next paragraphs bridge the four perspectives adopted in this paper to explore this.

Competitive action timing

Competitive actions at the firm level involve managerial choices on the timing of market entry, the availability of complementary goods, and the responses to competitors. At the firm level, a U-curve relationship exists between an optimum market entry timing and the probability of lockout, assuming market development is exogenous (Schilling, 1998). However, this optimum entry timing depends on the actions of complementors and competitors, their entry, the state of knowledge, user expectations, and the urgency to address their needs and environmental dynamics (Tiwana et al., 2010). Future research could integrate these factors and consider two or more competing platforms to investigate the timing of market entry vs the probability of lockout.

If entry time for platforms 1 and 2 is T_1, T_2, with $T_1<T_2$, and assuming the platform launch response delay $\Delta T=T_1-T_2$ is not big enough, and platform 2 is of higher quality, then platform 2 will dominate under given user expectations and increasing returns to adoption. Preannouncements always precede market launches therefore $TA_1<T_1$ and $TA_2<T_2$. If platform 1 is announced first, then $TA_1<TA_2$ and preannouncement response delay is $\Delta A=TA_2-TA_1>0$, and P_2 the probability of platform 2 to increase its market share and become dominant. However, it is possible that platform 2 undercuts the market launch date of platform 1 therefore $\Delta T>0$ or $\Delta T<0$. This generates four possibilities: (i) if ΔA increases then P_2 decreases, (ii) if ΔA decreases then P_2 increases, (iii) if ΔT increases then P_2 decreases, and (iv) if ΔT decreases then P_2 increases. Combinations of these statements can be made. They are summarised in Figure 3 below indicating areas where platform 1 or 2 is expected to dominate and stylised thresholds of transition between the two platforms. The thresholds depend on consumer expectations, and so does the eventual platform competition outcome. This could be extended to address multi-generational platform competition. Research on all the preannouncement and market launch timing possibilities and whether, and when, they alter the competition outcome becomes more difficult, and necessitates the use of modelling and simulation.

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4. Conclusions

A variety of theoretical frameworks and methods are used for platform competition research. Several methodological approaches are applied to platform competition research such as case analysis, regression analysis, social network analysis, and formal analytic models. Simulation as a methodological approach gains prominence as the socioeconomic context that underlies platform competition becomes increasingly complex.

The present article discusses reasons why modelling and simulation can be systematically used alongside qualitative research. Qualitative research may suffice to identify factor interactions and characterise their nature as reinforcing or disrupting, but not to evaluate the effect of their intensity and timing which are directly linked to a number of platform competition questions and managerial trade-offs discussed in this present paper. Empirical evidence suggests that the duration of platform competition processes historically seems to become smaller and more complex due to industry convergence. This suggests that delays in factor interactions that directly influence competition outcomes change and that competition outcomes are influenced by, and have an impact on numerous markets.

In order to cope with this increased complexity, the study of platform competition processes should go beyond the use of analytic methods and case studies. Current platform competition frameworks are not equipped or updated to account for these characteristics and recent future research outlines have not taken into account the potential that modelling and simulation has to offer. This paper addresses this gap, it explores the research directions it opens up and outlines nine research questions that could be addressed through modelling and simulation.

The questions focus on the timing and delays involved in platform competition processes and address the call for integrative, multi-level research that integrates micro and macro level issues, endogenous and exogenous factors and considers explicitly the role of platform developers and complementors. The hope is that research outcomes from modelling and simulation studies will feed back into theoretical frameworks and thus will keep them contemporary and relevant. As this entails the incorporation of various insights from multiple disciplines, platform competition will become more complex and this is where the value of modelling and simulation lies. The objective in this research outline was to provide a starting point for research work that will deliver this value.

The research questions developed were based on a review of established platform competition frameworks and future research articles. A limitation of the work is that the review represents our interpretation of the gaps we identified in the literature. Future research could test the validity of the research questions through a combination of literature and expert elicitation process e.g. Delphi study. This paper sought to bridge the theoretical frameworks in the literature with current and future research that will use modelling and simulation methods, but similar studies could consider groups of research methods e.g. statistical, formal, and qualitative.

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