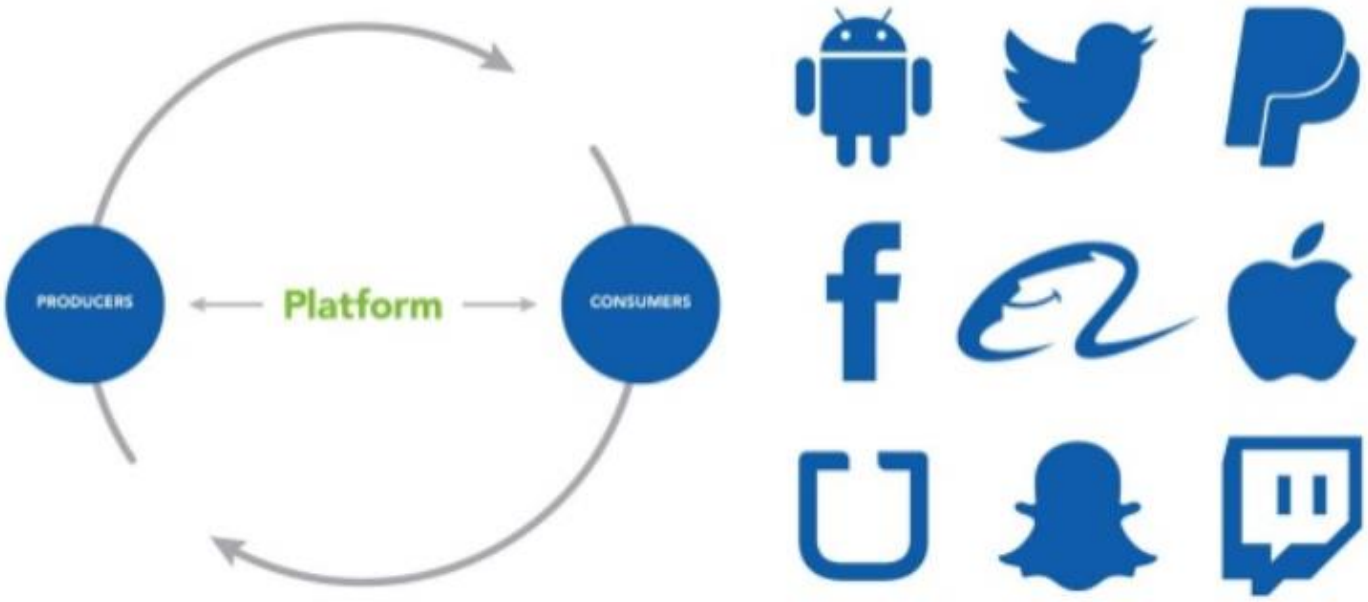
TU Delft
Delft University of Technology



Design and Governance of Platforms to leverage an ecosystem of complementors

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Management of Technology**

Faculty of Technology, Policy and Management

by

Ranjan Prajapati

Student number: 4738306

To be defended in public on July 18th, 2019

Graduation committee

First Supervisor	: Dr. G. (Geerten) van de Kaa, Section ETI
Second Supervisor	: Dr.ir. G.A. (Mark) de Reuver, Section ICT
Advisor	: V.C.M. (Vladimir) Sobota, Section ETI

Acknowledgements

This thesis marks the end of my master's program and journey at TU Delft. It was indeed the most challenging and promising experience which has helped me grow academically. My motivation to conduct research on this topic stems out from my deep interest and experience in working in the Information and Technology Services industry especially with digital platforms. I was intrigued to explore how platform firms can design and govern their platform so as to steer a large network of complementors to participate in their ecosystem.

I would like to extend my heartily thanks to my first supervisor Dr. Geerten van de Kaa for his continuous support in guiding me throughout all the phases of the thesis. His constructive feedbacks helped me a lot to improve the quality of the thesis. I would also like to express my gratitude to the chair of my graduation committee, Dr. Mark de Reuver for his expert comments and hard questions on the argumentations behind the hypotheses. Furthermore, I would like to especially thank my advisor, Vladimir Sobota who took his precious time to help me out during the entire phase of the thesis, especially during the data analysis phase and provide valuable feedback to improve my thesis.

Finally, the entire journey towards my graduation would have not been possible without the support of special ones who have always been my backbone. I would like to thank my parents and girlfriend for their dedicated love and support. They were always there for me. At last, many thanks to my friends, who were of extraordinary help in pondering over our issues and giving an upbeat diversion to calm my brain outside of this research.

Ranjan Prajapati

Delft, 2019

Executive Summary

Organizations in almost every industry are organizing their business activities around platforms. Platforms provides core products or services which act as a common structure for the development of wide variety of complementary products and services (Gawer, 2009). Well known high-technology firms such as Google, Amazon and Facebook offer their platform to complementors to build generative activities around their platform. A wide variety of complementary products generate greater value for end-users, in turn incentivizing a large network of complementors to adopt the platform. However, complementors have their own interest and goals and merely a high installed base alone cannot alone guarantee adoption of the platform. Thus, platform firms strive to attract a large number of complementors to gain competitive advantage over rival platforms.

Prominence of platforms fueled by Information Technology has raised research interest among scholars to study optimal design and governance strategies that can help incentivize complementors to participate in the platform. However, the focus was on platform firms and ignored the view of complementors treating all complementors to have the same interests and goals. This research explores the effects of design and governance strategies used by platform firms on complementors participation in the platform. Design can be conceptualized as how the interaction between the platform and other stakeholders take place whereas governance can be stated as how the control over platform is divided, who takes platform ownership and who is the decision-making authority.

Conducting a thorough study of design and governance literature on platform, this thesis analyzed three aspects related to design and governance of platforms – platform openness, exclusivity and boundary resources. This thesis also explored the moderating effect of platform age to determine

when exclusivity is beneficial for complementors. The hypotheses were tested in the context of video game console industry consisting of the seventh and eight generation consoles.

Platform openness is a broad construct that is difficult to measure. It was measured as complementors accessibility to produce complements for different markets. Accessibility to different markets appears to have a positive effect on complementors participation. When a platform offers products to heterogenous markets, complementors can reach a wider audience and will also face less competition than if all complementors operated in a concentrated market.

Producing exclusive contents for platforms gives higher bargaining power to complementors to appropriate higher rents in return for producing complements exclusively for the platform. However, as platform matures, increased competition within complementors disincentivizes complementors to develop exclusively for the platform and produce for multiple platforms to reach a wider audience. Thus, exclusivity in general has a positive effect on complementors participation with its effect decreasing as platform matures.

Platforms consists of core architecture and to transfer design capabilities to complementors, platform firms must provide boundary resources. Boundary resources aid complementor's development process and provides them with tools and resources to efficiently commercialize contents on the platform. This research makes a first attempt to measure boundary resources which has mainly been studied qualitatively. Boundary resources have been studied as cases and there is hardly any empirical evidence supporting its influence on complementors decision to join a platform. The results give empirical evidence that availability of boundary resources has indeed a positive influence on complementors participation as discussed in the previous literature.

This research opens avenues for future investigation into the topic. The conceptual model needs to be validated in different industries to extend its generalization. The conceptual model can also be extended to include more factors related to design and governance such as modularity, backward compatibility and pricing strategies.

Contents

List of Figures

List of Tables

1. Introduction

Technology platforms are disrupting traditional businesses by allowing firms to reach an interconnected network of ecosystem to gain competitive advantage. Google with its android platform has successfully penetrated different industries like automobiles, information technology, e-commerce and many more. These platform-mediated networks are often visible in high-tech industries like ICT, automotive, healthcare, etc. and provides a plethora of platforms around which the network operates (McIntyre & Srinivasan, 2017; Papachristos & Van De Kaa, 2016). Platforms can be defined as core products or services which act as a common structure for the development of wide variety of complementary products and services (Gawer, 2009). These platforms are characterized by direct network effects in which value of the platform increases with number of users of the platform (Katz & Shapiro, 1985). In addition, a large installed base of users captivates a variety of complementary products stimulating indirect network effects (McIntyre & Srinivasan, 2017). Thus, platform firms need to attract and collaborate with two or more sides of the platform – generally consumers and complementors (Hagiu, 2005). For example - Sony must attract both users and game developers for its gaming consoles.

With proliferation of platform-markets, several firms strive for platform dominance to capture market shares. For many of these dominant platforms, the support of complementors has been the driving force in achieving market dominance. Platform firms are dependent on complementors to solicit innovation and scale up their platform (Cusumano & Gawer, 2003). Sony won the DVD war against Toshiba by gaining support of a large network of complementors - movie studios and retail stores (Carrillo & Tan, 2015). In the dynamic evolving ICT industry, platform firms face rapid competition both from its competitors as well as its complementors making the environment more complex (Cusumano & Gawer, 2003). In the smart healthcare platform, Apple Health

competes with its competitor Google Fit as well as faces fierce competition from its complementor Fitbit which uses Apple's platform for its wearable devices. However, firms can gain competitive advantage by appropriately stimulating value co-creation within its network of complementors (McIntyre & Srinivasan, 2017).

The competition now revolves around attracting a large number of complementors committed to the platform. With the need of increasing platform innovation, challenges emerge in designing platform to support the generative activities of the complementors. This raises technological complexity of collaborating complementors around platforms. Decisions on design also impact the way platform owners can govern the activities of complementors (Isckia, de Reuver, & Lescop, 2018). By imposing governance mechanisms, platform owners make sure that complementors' goals and objectives are aligned with platform owner's vision of the platform. Thus, Platform firms cannot neglect the importance of complementor dynamics in their success and must study how to design and govern their platform to leverage support of complementors. This research will aid the existing literature by exploring the effect of design and governance aspects of platform on complementors participation in a platform.

1.1 Related Literature

Omnipresence of platforms in almost every industry make it a complex object to research. With the evolution of the platform ecosystem, firms face complex challenges in managing the ecosystem since platforms are a completely different entity than traditional businesses. Ecosystem refers to the platform owner along with its complementors who generate innovation around the platform and make it attractive to the end users (Jacobides, Cennamo, & Gawer, 2018). Jacobides et al. (2018) suggested that modularity enables the emergence of ecosystem by allowing a large number of complementors to participate in the platform and utilize its installed base. Modularity though

being mainly studied as a technical aspect of platform also enables platform owners to control and coordinate the activities of the complementors. Scholars have investigated how degree of openness of the platform can have significant effect on platform owners and under what conditions opening a platform is desirable (Anvaari & Jansen, 2010; Benlian, Hilkert, & Hess, 2015). Atari's inability to regulate the video game market lead to its demise in the 1983 because it could not lock in unauthorized development of games (Gawer, 2009).

A few of the studies have taken the perspective of complementors in understanding the platform ecosystem. Boudreau (2010) compared different control mechanism for the platform and found out that one strategy had a profound effect than the other. Choi, Nam, and Kim (2017) in their study also found out that opening the platform for a group of complementors had a positive effect on complementors intention to join a platform. However, opening the same platform to other group of complementors had a negative influence on complementors' intention to participate in the platform. Economists have tried to identify how firms take advantage of the network effects by setting pricing strategies for the two side of the market (Armstrong, 2006; Chakravorti & Roson, 2006). Pricing is also used as a governance mechanism to coordinate the platform ecosystem and solve the chicken and egg problem (Schreieck, Wiesche, & Krcmar, 2016).

In broad terms, these studies have examined how specific design and controlling mechanisms play a role in the success of platform from different lenses. Design can be conceptualized as how the interaction between the platform and other stakeholders take place whereas governance can be stated as how the control over platform is divided, who takes platform ownership and who is the decision-making authority. Koch and Kerschbaum (2014) investigation on application developers' decision to participate in a platform revealed that it is highly influenced by design and governance decision taken by platform firms. Thus, not isolating both aspects of platform and following an

integrated study to understand these factors is highly needed to contribute to the theory of platform ecosystem.

1.2 Research Gap

It is evident that literature on platforms is highly fragmented and has focused on specific aspects of platforms. There has been a little study on platforms that integrates different aspects of platforms (Schreieck et al., 2016). For example, platform openness has mainly been studied as giving access to the core technology, however it can also facilitate coordination and induce competition between complementors and help platform firms achieve its strategic goals. The degree of openness would in turn affect how platform firms should pursue its design strategy. A high degree of openness would mean that the platform firm should follow a simple design strategy to meet the needs of diverse complementors and avoid complexity. Whereas, a platform having a low degree of openness can pursue a complex design to control the quality of the complements. This thesis argues that that different aspects of platform could not be studied in isolation but needs to be studied in tandem to explain their symbiotic relationship. Moreover, majority of the studies have adopted qualitative approaches which demands quantitative validation.

In the recent years, authors have tried to bridge in the gap between different perspectives on platforms and called up for a comprehensive research in studying the dynamics of platform competition (Gawer, 2014; McIntyre & Srinivasan, 2017; Schreieck et al., 2016). The importance of complementor dynamics has received limited attention in the literature and assumes complementary products as exogenously available (McIntyre & Srinivasan, 2017). However, platform firms can strategically encourage complementors, and choices made them can have significant effect on complementors participation in the platform. Some studies have embodied empirical methods to understand complementor's motivation or intention to stick to an open

platform (Choi et al., 2017; Schaarschmidt, Homscheid, & Kilian, 2019). However, their sample size was too small and consisted of hobby developers that makes it difficult to generalize the findings in an industry context.

1.3 Relevance of Research

Academic Relevance

This thesis will contribute to the existing research by providing a deeper understanding of the design and governance aspects of platforms. Design can be conceptualized as how the interaction between the platform and other stakeholders take place whereas governance can be stated as how the control over platform is divided, who takes platform ownership and who is the decision-making authority. This paper argues that design and governance mechanisms have been studied in isolation and there is a need to explain their interdependence. The way a platform is designed effects the way it can be governed. Moreover, decisions taken by platform firms have a significant influence on the decision of complementor to participate in the platform. Past focus has been to explain platform dominance, giving limited attention to complementor's view. This study will attempt to explain the factors through which platform firms can design and control their platform to leverage indirect network effects. From an ecosystem perspective, it will look at the factors that complementor deem important in their decision to participate in a platform. Thus, this study attempts to understand the influence of design and governance decisions made by platform firms on the complementors participation in a platform.

Managerial Relevance

With a rapid surge in businesses following a platform strategy, platform owners need to differentiate their platform from rivals to achieve competitive advantage. They need to attract

developers of complementary products who act as a value creation mechanism for the platform and attract more consumers towards it. Managers of these firms often face dilemmas in finding the right set of design and control mechanism for their platform ecosystem. By exploring the effect of the design and governance aspect of platforms on complementors participation in a platform, this research will help industry experts to gain a deeper understanding of the dynamics that stimulate complementors and deem important to them. The findings of the research will also act as a guideline for incumbent firms to effectively pursue their platform strategy and gain the support of an array of complementors.

1.4 Research Objective

This thesis aims to meet the follow research objective:

"***Analyze how specific design and governance aspects of platforms explains complementors participation in a platform*** **"**

Aspects here can be treated as factors that can have a positive or negative influence on complementors participation in a platform. This thesis will attempt to explain complementors dynamics in greater. Moreover, it will present a conceptual model for the influence of design and governance aspects on complementors participation in a platform. Ultimately, this research will provide recommendations for platform providers to aid their decisions on designing and governing their platform to attract a large network of complementors.

1.5 Research Questions

To arrive at the research objective, the following main research question is formulated.

"What are the effects of the design and governance aspects of platforms on complementors participation in a platform?"

The answers to the main research question will be explored by delving into the following sub questions.

1. **According to current literature, what are the factors related to design and governance of platforms and their influence on complementors participation in a platform?**

Various researchers have either studied the appropriate design decisions for a platform or the governance mechanism through which firms can effectively control the evolution of the platform. These studies have looked at specific factors related to design and governance aspects of platform. Firstly, this sub research question aims to compile the existing literature around design and governance of platforms into a conceptual model.

Secondly, it will explain the design and governance aspects of platforms from the complementor's perspective. It aims to hypothesize the influence of the factors related to the design and governance of platforms on the participation of complementors in a platform. Thus, the focus will be to derive conclusions from previous investigations on how these factors influence complementors motives to participate in a platform and actively contribute to the evolution of the platform.

2. **What are the effects of design and governance factors on complementors participation in the video game console industry?**

The focus of this sub research question is to test the hypothesis formulated by answering the first sub research questions. It is crucial to answer the main research question since it will quantify the influence of the conceptual factors on complementors participation in a platform. An important activity in order to arrive at the answer to this sub question is to collect longitudinal data from the

video game console industry. Video game console platforms will be relevant to the study because of its rapid proliferation in the market with many competing platforms and a wide variety of game developers as complementors. Moreover, the video game industry has seen several era of platform competitions with emergence of dominant platforms (Srinivasan & Venkatraman, 2010). The results of this question will help to verify the hypothesis laid down in the thesis and develop a validated model for researchers and industry experts.

2. Theory

2.1 Platform

In this era of intense, competitive and dynamic business environment, companies face a lot of pressure to rapidly develop new products than their rival firms. Product life cycle has become shortened due to rapid technological and market changes with user needs evolving and becoming heterogenous over time (Scholten & Scholten, 2011). In order to meet the diverse and complex demand needs by end users, firms strive to leverage their core competencies as well as introduce diversity in their offerings by fostering open innovation and organizing their activities around platforms (Halman, Hofer, & van Vuuren, 2003; Scholten & Scholten, 2011). Firms can benefit by co-creating values outside their boundary and expand their offering by coupling it with streams of innovative products and services. Thus, the basic idea behind the concept of platform is to decouple the common elements to provide a base for the creation of different elements to meet differential needs of the firms (Halman et al., 2003).

Although platforms have been studied a lot in the literature, there has been no consensus on the definition of platforms. To some, platforms are markets that helps network of users to transact with each other which would otherwise have not been possible (Eisenmann, Parker, & Alstyne, 2010). Airbnb operates an online marketplace connecting network of guests and hosts. Platforms have also been defined in technical terms as a core architectural design that facilitates communication between complementary systems using common set of interfaces (van de Kaa, de Vries, & Rezaei, 2014; Yang & Jiang, 2006). Mastercard allows merchants and online retailers to use its payment platform's architecture by use of common interfaces known as APIs. These different definitions stem from the difference in perspectives on which platforms have been studied so far. However,

this thesis would adopt Gawer (2014) recent definition of platform as "evolving organizations or metaorganizations 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."

2.2 Platform Ecosystem

The existence of platforms leads to the emergence of platform ecosystem. A platform ecosystem consists of a platform provider and its complementors (Jacobides et al., 2018; Schreieck et al., 2016). Complementors are the network of firms that produce complementary innovations for the platform provider. By participating in the platform ecosystem, complementors can gain access to the platform's end-users (Jacobides et al., 2018). Complementary products are the goods and services primarily developed on the platform which increase the value of the core platform (McIntyre & Srinivasan, 2017). DVD players alone have no value for its users unless they can buy cassettes to play content on it. Thus, platform ecosystem takes the form of "hub and spokes" with hub at the center and spoke at the periphery connected to the central hub with shared rules, standards and technologies (Jacobides et al., 2018). This relationship between hub and spoke need not be bounded by contractual agreements or any hierarchical control. Figure 1 shows how platform ecosystem is structured.

In this paper, hubs will interchangeably be called as platform providers or platform firms or platform owners or platform sponsors. In the same way, spokes will be referred as complementors or producers/developers of complementary products. The next section will discuss the start of art literature on platforms and the different perspectives taken by scholars to study platforms.

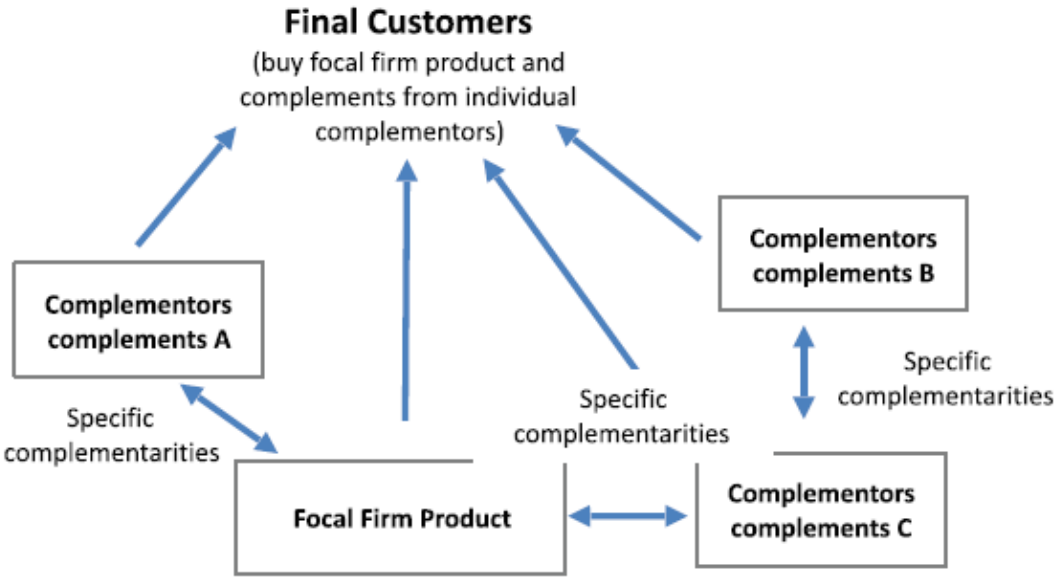


Figure 1. Structure of Platform Ecosystem - Adapted form Jacobides et. Al (Jacobides et al., 2018)

2.3 Different perspectives on platforms

Studies on platform have been dominated by two different theoretical perspectives – the economic perspective and the engineering design perspective (Gawer, 2014). According to the economic perspective, scholars have viewed platforms as two-sided market and studied the dynamics related to platform competition (Armstrong & Wright, 2006; Chakravorti & Roson, 2006). The interaction between the two sides of the market accrues a mechanism called network effects (Gawer, 2014). The value of a platform increases when more users start using it, also the platform become valuable to potential users. Since platform joins two sides of a market, it captures value by the existence of same side/direct network effects and cross-side/indirect network effects.

Direct network effects arise when the consumers are willing to pay for the product when there are more consumers on the same side of the platform (Filistrucchi, Geradin, van Damme, & Affeldt,

2014; van de Kaa & de Vries, 2015). Social media platforms like Snapchat and Facebook becomes valuable for end users when there is a large network of users using it. Indirect network effects arise when the value of a platform to its users on one side depends on the presence of users on the other side (Evans, 2009). Airbnb becomes more valuable to buyers with an increase in the number of real estate agents (sellers) and vice versa. Platform firms must cater to the needs of both sides of the platform and grow users on both sides simultaneously. However, users on one side would hesitate to join without the presence of other side leading to the "chicken and egg" dilemma for platform firms (Evans, 2009; McIntyre & Srinivasan, 2017).

Economists have tried to identify how firms can take advantage of the network effects by setting pricing strategies for the two side of the market and avoid the "chicken and egg problem" (Armstrong, 2006; Chakravorti & Roson, 2006). Firms heavily subsidize one side of the market in order to attract the other side. Scholars have tried to explain the dynamics that helps firms benefit from network effects like installed base and availability of complementary products (McIntyre & Srinivasan, 2017). Thus, the presence of network effect is an essential feature of platform that demarcates it from traditional business forms and shapes competition in the market.

From an engineering design perspective, platforms have been studied as artefacts that drives innovation across industries (Gawer, 2014; McIntyre & Srinivasan, 2017). It states that the design of platforms can help firms achieve economies of scope in innovation. Gawer (2014) defines economies of scope in innovation as the reduced cost of developing product 1 and 2 jointly instead of independently developing product 1 and 2. This can primarily be achieved by following a modular approach to design platforms (Jacobides et al., 2018). Therefore, this view sees platforms as stable components upon which innovation occurs on modules by using stable interfaces (Gawer, 2014; Schreieck et al., 2016).

Primarily this perspective focuses on the design of platforms to accrue the benefits of network effects and facilitate collaboration with complementors (McIntyre & Srinivasan, 2017). In the recent years, a burgeoning body of literature have made its way into the mainstream information systems research. Scholars have studied the evolution of platform architecture and how platform's design such as modularity and interfaces act as a collaborative mechanism (Tiwana, Konsynski, & Bush, 2010). Some have studied the governance mechanism employed by firms providing an IT platform (Ghazawneh & Henfridsson, 2013; Tiwana et al., 2010). The information system (IS) stream adds to a deeper understanding of IT platforms and stresses the distinction between digital and non-digital platforms (de Reuver, Sørensen, & Basole, 2018). In broad terms, these studies have examined how specific factors play a role in the success of platform from different lenses.

2.4 Design and Governance of Platform ecosystem

Followed by the success of Microsoft's operating system platform, scholars tried to comprehend how platform ecosystem can be designed and controlled which subsequently can aid the platform to become the de facto standard in the industry (Schreieck et al., 2016). They looked at characteristics, design requirement and control mechanism needed for a successful platform. Platform incorporates a design that contains an architecture for the core product and provides the infrastructure for the interaction between the two sides (Bakos & Katsamakas, 2014). A robust platform design aids platform firms to minimize their development efforts on future generation products and reduce entry time to the market (Martin & Ishii, 2002). However, the increasing number of complementors raises more concern on how platform governance should be structured with the rapid increase in competition in the market. The question for platform owner then is who has decision rights on the platform, what should be governed and how can it be controlled. Following the right governance decisions, platform firms can attract different actors to the platform

and incentivize them to align with platform owner goals. Platform ecosystem raises the complexity of relationship between the actors beyond the control of the platform firm. However, successful platform firm achieve this by strategically orchestrating the right design and governance strategy (Smedlund & Faghankhani, 2015).

Isckia et al. (2018) posit that platform design and governance are heavily related and influence the value cocreation within the network of complementors. While the way a platform is governed is determined by the vision of the platform owner in maintaining a leadership, this can be achieved by following an appropriate design strategy. Complementors invest their time and effort to contribute to a platform, making these aspects an important factor in their decision for platform selection. An open platform can give them access to the installed base of the user but at the same time this means intense competition between the complementors (Boudreau, 2010). Just as the platform owners face tradeoffs in designing and governing platforms, complementors also face tradeoff's in their decision.

This paper will attempt to explain three design and governance aspects of platforms – openness, boundary resources and platform exclusivity. All the three concepts are relevant to both design and governance of platforms. For example, degree of openness defines how platform firms design the platform to give access to its complementors. By adjusting the degree of openness, platform firms can dynamically govern their platform as seen in the case study of Apple and Google (Schaarschmidt et al., 2019). The concern for platform owners is to attract larger magnitude of generative activities by complementors and align their interest to meet the goals of the platform. They must motivate complementors and understand that they are crucial resources for establishing dominance in the market. Therefore, the paper will examine the influence of design and governance decision taken by platform firms on the participation of complementors in a platform.

In the next section, the concepts will be explained from the perspective of complementor and then lay down the hypotheses.

2.4.1 Openness to different markets

Openness is defined as the ease of restrictions on the involvement, development and the commercialization of the underlying technology of the platform (Boudreau, 2010; Eisenmann, Parker, & Van Alstyne, 2008). Openness has mostly been studied from the perspective of platform owners. Platform owners often face a tradeoff when they decide to open a platform –what degree of control and access to give up for the platform (Boudreau, 2010). Giving up control reduces platform owner's share of profit by removing any entry or exit barrier for complementors resulting in high competition, low switching cost and low fear of lock in (Boudreau, 2010; West, 2003). While giving access to the platform increases the adoption by complementors, diversity of complementary products and innovative solutions (Benlian et al., 2015).

Benlian et al. (2015) studied openness from complementors' perspective and formulated a comprehensive conceptualization of complementors perceived platform openness (PPO) integrating the technical and business aspects of platforms. They defined PPO as the degree to which a platform is open as perceived by its complementors. This section will build its theory and hypothesis on Benlian et al. (2015) complementors' PPO distinguished with different facets of accessibility. Accessibility relates to the degree of restriction on the use of platform against distinct set of users of the platforms – end-users and complementors (Benlian et al., 2015; Setzke, Böhm, & Krcmar, 2019). Their study investigated a lot of factors like accessibility to the core technology, terms and conditions, guidelines and constraints to the use of platform (Benlian et al., 2015). We extend their conceptualization by adding a different dimension to platform openness as perceived and measured by complementors.

Consumers have heterogeneous demands and platforms firms can see an opportunity to expand to markets it has not explored yet. For example, the first smartphone applications were used as personal productivity tools like calculator, address book, note pad, etc. But now the smartphone applications have reached almost every industry including automobiles, manufacturing. healthcare, IOT, and many more. By creating additional opportunity for complementors to reach an expanded market, platform firms can increase the magnitude of indirect network effects. Giving access to the platform vertically to different markets would allow complementors to focus on other different streams of solutions for that particular market thereby decreasing the degree of competition if the platform was open to just one market. Parker and Van Alstyne (2008) found that reducing competition between complementors benefits platform owners. An increase in platform share in turn incentivize a large number of complementors to join the platform. Boudreau (2010) studied platform openness in the context of mobile handheld devices. His study showed empirical evidence of increase in hardware complements when a large number of complementors from heterogenous industries were granted access to the platform.

Accessibility to different markets can be defined as the ease of restriction on the use of platforms to develop and commercialize complementary products for heterogenous market. When the complementors do not have restrictions to develop for other markets, they can utilize this opportunity to develop innovative products to target different markets to increase their revenue streams. In turn, it incentivizes the complementors to participate in an open platform where they can simultaneously build solutions for different markets rather than finding it difficult to sustain a highly competitive market. This leads to the first hypothesis of the paper:

H1: Accessibility to different markets has a positive effect on complementors participation in a platform.

2.4.2 Boundary Resources

This section discusses the influence of availability of boundary resources on complementors participation in a platform. Boundary spanning has been studied in Industrial Organization literature as a collaborative governance mechanism that can reduce physical and social barrier between different group of actors, firms and institutions (Termeer & Bruinsma, 2016). Physical barrier refers to the technical obstacles that hinders the interaction between actors whereas social barriers refers to the difference in knowledge between group of actors. Thus, firms form boundary spanning arrangements such as common rules, processes, technologies and regulations to ease their interaction with different actors (Fennell & Alexander, 1987; Termeer & Bruinsma, 2016).

As technology evolves and become more complex, firms face issues in designing the technology so that a large group of complementors can use it without even exposing the core technology. Most of the platform being empowered by information technology solves this issue by providing boundary resources to the developer of complementary products. Boundary resources refer to the tools and regulations provided by platforms that serves as an interface between the platform owner and the complementor (Ghazawneh & Henfridsson, 2013). In other words, boundary resources allow firms to shift their design capability to the complementors who develop diverse product for the end-users (Ghazawneh & Henfridsson, 2013). Also, the design of platform architecture greatly influences the design of boundary resources (Bianco, Myllarniemi, Komssi, & Raatikainen, 2014). In this regard, firms' strategy is to design the platform in such a way that they can combine economies of scale, differentiate product and create incentive for complementors (Ghazawneh & Henfridsson, 2013).

Most of the studies investigating boundary resources have considered the perspective of platform owners and focus has been on either on technical or governance aspect of platform (Bianco et al., 2014; Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015; Ghazawneh & Henfridsson, 2013). In the platform literature, boundary resources have been studied as API and Software Development Kits (SDK) provided by platform owners to facilitate the involvement of complementors (Eaton et al., 2015; Ghazawneh & Henfridsson, 2010; Schreieck et al., 2016). Some authors have tried to study boundary resources as control mechanism to regulate behavior of complementors (Ghazawneh & Henfridsson, 2013). Though boundary resources are provided as technical artefacts, it can be used as effective control mechanism to create a sustainable platform free from infringement.

Karhu, Gustafsson, and Lyytinen (2018) studied how complementors can also use boundary resources to fork a platform. Forking a platform is seen as an exploitive action used by complementors to launch a competitive platform by copying the core elements of the host platform. Availability of boundary resources helped Amazon to fork Google's platform and launch their own operating system by building on the capabilities of Android platform (Karhu et al., 2018). Their studied added a new dimension to boundary resources – from coopetition to competition. Ghazawneh and Henfridsson (2013) introduced the concept to self-resourcing meaning that complementors can develop additional boundary resources to ease their development. By modifying the boundary resources or introducing new resources, platform firms can gain additional control over the platform as well as defend itself from competitive behavior (Karhu et al., 2018). Thus, it is evident that the way boundary resources are designed also determines the way platform firms can exercise control over the complementors and its resources.

Boundary resources can be seen as critical element in decision to open the platform to complementors. It can help to manage the tension between securing the control of the platform infrastructure or institution as well as maintaining the generativity of the platform (Eaton et al., 2015; Mukhopadhyay, de Reuver, & Bouwman, 2016). It is an excellent mechanism for feedback from the complementor community because insufficiency in present boundary resources can restrain complementors to participate in the platform or involve in infringement and re-sourcing (Ghazawneh & Henfridsson, 2010). In return, platform firms can provide additional boundary resources to cater to the demands of complementors to increase its network of innovators.

From a complementors' perspective, boundary resources are important for one prime reason. Complementors' decision to join the platform is highly dependent on the platform owner's willingness to share resources and make collaboration transparent. Resources can either be technical resources like API and SDK or social such as documentations and complementor communities. (Bianco et al., 2014). Ghazawneh and Henfridsson (2010) in their case study involving Apple's iOS found that every time a new boundary resource was introduced, the number of applications for the platform increased. Apple distribute SDK for its platform that contains the tools to develop mobile application as well as provide the necessary documentation that diminishes the cognitive barrier in interacting with the platform. It also has a strong developer community to facilitate collaboration between developers. Therefore, when platform firms share these resources, complementor adheres to these guidelines, and can make sure that the complementary product follows the platform standards. This leads to the second hypothesis.

H2: Availability of boundary resources has a positive effect on complementors participation in a platform.

2.4.3 Platform Exclusivity

Formation of exclusive contracts with complementors has been used as a competitive strategy by platform owners to differentiate their products from the rival firms (Carrillo & Tan, 2015; Hagiu & Lee, 2011). Consumers intend to participate in a platform that has a wide range of complementary products and high quality content (Hagiu & Lee, 2011). To make the platform valuable to end users, platform firms attract and retain talents through contractual agreements to provide high quality and attractive content for their respective platform. Platform exclusivity refers to the ability of platform firms to restrict complementors to develop complementary products for rival platforms (Corts & Lederman, 2009). This setting is prevalent in a variety of industry setting such as print media, game consoles, software, telecom operators, etc. The success of the video streaming platform Netflix over incumbents was primarily made possible through acquisition of exclusive rights by high end contents providers like Walt Disney, Warner Bros and many more.

Platform firms needs to consider strategic trade-off when deciding on whether to pursue exclusive contracts with complementors or not. On one hand, gaining exclusive rights from complementors will allow them to secure unique contents for the end-users, enjoy the benefit of indirect network effects and appropriate higher rents (Gil & Warzynski, 2015). On the other hand, in the pursuit to dominate the market with exclusive complementors, platform firms have to sacrifice revenues and charge less royalties from complementors in exchange for exclusive rights (Mantena, Sankaranarayanan, & Viswanathan, 2010). Thus, platform owners also need to consider a multitude of factors before pursuing an aggressive exclusivity strategy.

Exclusivity decisions decides whether the platform owner want to multi-home one side of the market. It also serves as a control mechanism to exercise power over the users as well as tightly control the evolution of complements. These decisions also have implications on the incentive to

complementors to join the platform. Thus, this paper also argues that apart from considering exclusivity as a competitive strategy, it also has significant effect on the design and governance aspect of the platform.

If platform were to not pursue exclusive contracts with complementors and allow multihoming, it would lead to decrease in the quality of complements because of the complexity in the technological architecture between rival platforms (Cennamo, Ozalp, & Kretschmer, 2018). The outcome of whether complementors tend to multi-home would also have implication for platform owners in their decision to design the platform. Then they are faced with two dilemma (i) to stick to this market mechanism and pursue a simple platform design to allow low quality but diverse range of complements or (ii) to go against market conditions and pursue a complex platform design to produce high quality exclusive content (Cennamo et al., 2018). This dilemma makes it worse for the platform owner given the previous trade-offs regarding appropriating rents from complementors.

The decision of complementor to join a platform is not only dependent on the installed base of user of the platform firm but also on the installed base of competing platform. Their incentive to license their product to a platform is determined by the potential of the market that they can reach through the firms installed base (Cennamo & Santaló, 2009). However, in market where incompatible platform exists and market share are relatively similar, complementors tend to multi-home because they can spread the fixed development costs over multiple platforms (Corts & Lederman, 2009). Incompatibility here refers to the state when complementary solution developed for one platform does not work with other platforms. Given the ability to market their product to a broader installed base of users in presence of incompatible platforms, this advantage however comes with a price. Apart from the fixed development cost, complementors need to spend

additional expenses to port the product to multiple platforms and possibly pay higher royalties to platform providers due to reduced network externalities (Gil & Warzynski, 2015).

On one hand, pursuing exclusive contracts with platform firms detains complementors to expropriate rents from a large mass of end-users. On the other hand, exclusivity helps complementors to aid their financing from platform firms in return of rights to distribute and market complements exclusively on the platform (Lee, 2013). This clearly depicts the tension complementors face on their decision to either produce products for multiple platform or solely contribute to a single platform. In the literature, the effect of exclusivity on competition between complementors has been quite debatable. While some studies show exclusivity deters entry to market and thus smoothen competition, other estimates that it can even increase competition (Cho, Kumar, & Telang, 2014).

From the above discussion, it is not clear whether exclusivity can incentivize a large network of complementors to participate in the platform and exclude other rival platforms. However, the benefits of exclusivity outweigh selling of complements also on the rival platforms. Complementors competition depends on the quality of content. Cennamo et al. (2018) in their study found that if complementors decide to produce simultaneously for different platform, there is a drop in the quality of complements. Consumers deems high quality content important in their purchase decision. It makes sense for complementors to enter into exclusive contract since they also benefit from the release strategies of the platform owner (Gil & Warzynski, 2015). Carrillo and Tan (2015) in their modeling of competition in two-sided market proposed that complementors who enter into contractual agreement are better able to extract profits than complementors who do not pursue exclusive contracts. Cennamo and Santaló (2009) also found that platform share increases with increase in exclusive content. All these factors incentivize a complementor to

participate in exclusive contracts with platform owner so that it can appropriate rents, adhere to a higher quality and sell to a large surplus of consumers who deem quality as a proxy for must-have complement. This leads to the third hypothesis.

Hypothesis 3A: Platform exclusivity has a positive influence on complementors participation in a platform.

Scholars have tried to investigate conditions under which exclusive contracts emerge (Chowdhury & Martin, 2016; Lee, 2013). Lee (2013) study of the presence of exclusive contract in the US video game industry revealed that exclusive contracts was largely pursued by new entrants to make the platform appealing to the end-users. On the contrary, though incumbents could have secured exclusive contracts, chose not to do it given their ability to appropriate rents from a large installed base of users. In mature markets, platform owners adhere to a threshold quality under which new exclusive contracts with complementors deem insignificant resulting in higher exclusivity in the nascent stages (Mantena et al., 2010).

When the platform is its early stage, complementors face less competition. As platform matures, its installed base increases. The indirect network effects plays role in attracting more complementors to the platform (McIntyre & Srinivasan, 2017). Complementors will start facing high competition in the market. In crowded platforms with intense competition, complementors may be reluctant to produce high quality complements exclusively for the platform due to limited market exposure (Cennamo & Santaló, 2009). Also, if a platform firm pursue aggressive exclusivity strategy in its mature stages, complementor will tend to question the control strategy applied by the platform as well as would consider themselves locked in with a particular platform. When the benefit of multi-homing outweighs the exclusive rents a complementor can earn through the high-quality exclusive complement, the whole network of complementor would chose to

develop for multiple platform. Though the competition would intensify but would lead to more efficient innovation by complementors in turn allowing them to reach a mass market for their complements (Cennamo & Santaló, 2009). Moreover, end-users would benefit from a diverse range of complementary products irrespective of the platform they are a part of. This leads to the last hypothesis.

Hypothesis 3B: The impact of platform exclusivity on complementors participation decrease with platform age.

The conceptual model is shown in figure 2.

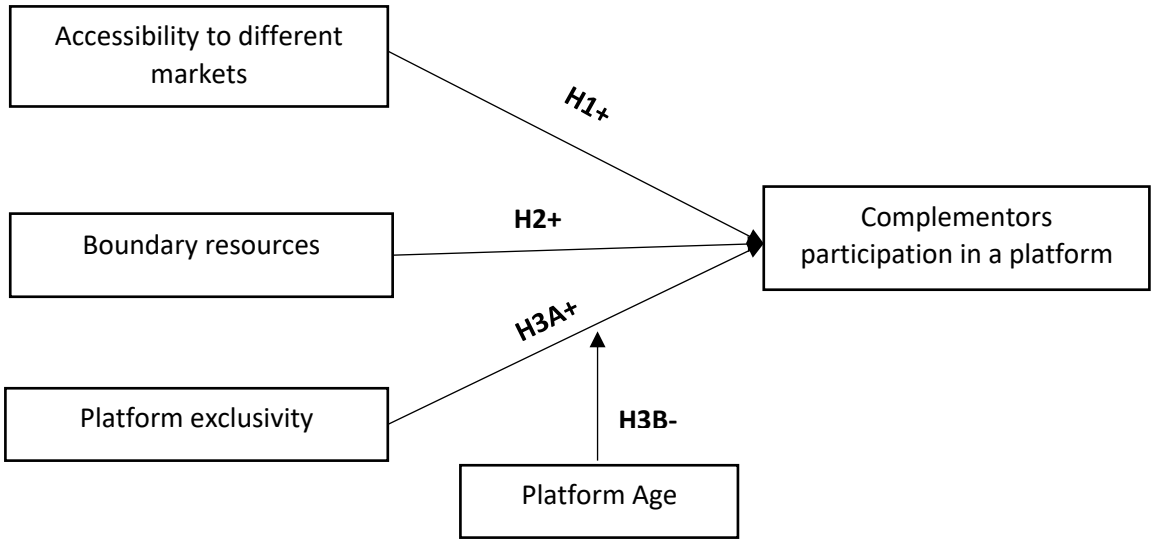


Figure 2. Conceptual Model

3. Methodology

3.1 Research Setting

The video game console industry is a good setting to understand the influence of design and governance decision of platform owners on the intention of complementors to join a platform in the high-tech ICT sector. This industry experienced a global sale of approximately 81.5 billion USD in the year 2015 and is forecasted to surge to 138.4 billion USD by 2021 (Figure 3). This comprise of combined sales of video game consoles (hardware) and video games (software). The video game industry exhibits the presence of strong network effects. A video game console alone is not useful for the consumers unless they can have access to a diverse portfolio of video games. In the same way, complementors will prefer to join a console that has a large user base. Thus, value to consumers for using a particular console is indirectly dependent on the number of complementors developing for the platform.

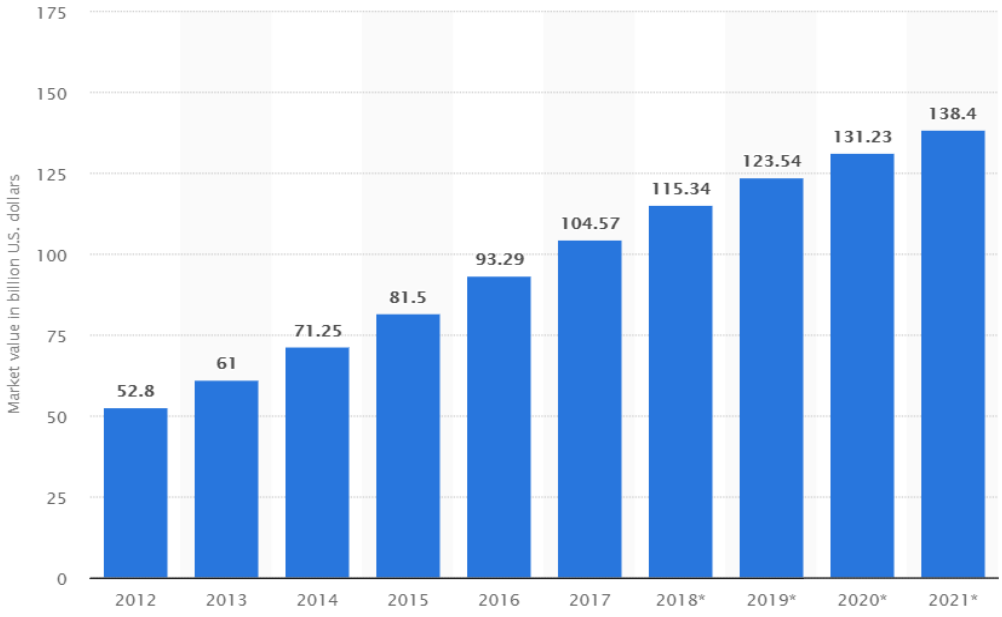


Figure 3. Global video games market value from 2012 to 2021 ("Statista," 2019)

This industry setting is particularly interesting to study due to two important reasons. Firstly, the rise of the industry is attributed to the rapid technological changes leading to the emergence of eight generations of video game consoles with new generations introduced approximately every five year (Srinivasan & Venkatraman, 2010). Each generation had fought fierce battle to secure a dominant position. However, this has not led to the formation of any standard and the consoles have predominantly been incompatible with each other. As a result, consumers are very selective in their decision to buy a platform and prefer a console that has a support of high quality and diverse games. Thus, the platform that provides diverse game titles and secures more exclusive contents attracts more consumers to buy their platform.

Secondly, the success of the industry is primarily due to platform owner's ability to gain access to a large network of complementors to produce high quality games (complements) that makes the platform (video game consoles) attractive for the users. Apart from fighting fierce wars with rivals on end users, platform owners also compete to secure support of a wide range of complementors, in this context the video game developers. Moreover, in presence of incompatible consoles, complementors intention to join a platform is dependent on several factors such as installed base, quality of the console, revenue sharing, competition within consoles and control mechanism used by platform owners. These competitive dynamics make it an ideal setting to study the factors that incentivize complementors to support a platform (Corts & Lederman, 2009).

3.2 Data Collection

For this research purpose, the thesis will congregate an extensive database derived from multiple sources. Quarterly global sales data for consoles and game titles will be obtained from VGChartz from the year 2005 to 2015. This longitudinal period spans two generations of consoles and their respective game titles – the seventh and the eighth generations. VGChartz is an industry research

firm that hosts a game database of over 40,000 titles and 1.5 million data points. The sales dataset will be extended by documenting every game title's release year, publisher, developer, genre and the platform on which the games were released. The dataset will be validated by cross checking it will another source www.mobigames.com. Mobigames is claimed to be the "oldest, largest and most accurate video game database" covering a range of consoles starting from 1950. Mobigames has been used in similar industry setting to gather dataset on game titles (Corts & Lederman, 2009). The dataset will also be supplemented by information on the game engines available for the console. This information will be extracted by Internet Game Database (IGDB). IGDB provides game developers, designers and marketers with valuable data that gives insight into the industry, improve decision-making and helps them create a survival strategy. The information about the release dates and platforms supported by the game engines are validated and gathered with online news and press releases. Altogether the dataset will comprise of game titles released over years for 6 video game consoles spread across two different generations.

3.3 Operationalization of Constructs

3.3.1 Dependent Variable : Complementors participation

Most of the studies measuring indirect network effect uses number of complements as a proxy for platform success (McIntyre & Srinivasan, 2017; Srinivasan & Venkatraman, 2010). This study goes beyond this conceptualization and measures the strength of indirect network effects as the number of complementors participating in the platform ecosystem. Participation of complementors is an important determinant for the number of complements produced and platform's performance. The more complementors participate in the platform, the more complementary products would be available for the platform. Then, platform owner's objective is to secure increased participation of complementors as compared to its competitors. Complementors participation in a platform is

measured as proportion of unique game developers for platform i over total game developers in the quarter t.

3.3.2 Independent Variables

Accessibility to different markets

Video game console manufacturers need to cater to heterogenous needs of consumers. A console that only provides games for a particular market may lose out on consumers in other markets. For example, if a console manufacturer targets to provides games only in the action segment can lose consumers that like to play adventure games. In other words, if a console is only known for its superior quality in the action genre, consumers would prefer to move to a platform that provides high quality games for a range of genres. In the same way, game developers will prefer to join a platform that allows them to reach different markets since they can reach an extended base of consumers. This thesis operationalizes accessibility to different markets as the proportion of game genres produced for platform i over total game genres developed in the quarter t. This paper uses genres as a proxy to measure markets. A particular genre represents a mass of users with distinct demands. Thus, games titles for different genres can be represented as heterogenous markets a console provider reaches. It has also been used by Srinivasan and Venkatraman (2010) to account for the variety of ties a platform owner has with its complementors and its impact on platform's performance. By providing complementary goods for heterogenous market, the platform firm can govern its platform by smoothening the competition between complementors. Also, the degree of opening the platform to different markets would have significant effect on the design of platform. If the platform is accessible to complementors developing for heterogeneous market, it should pursue a simpler design than its rivals to support the generative activities of complementors. However, if the platform firm has its vision of specializing in a specific market, it should pursue

a design strategy that can help complementors to develop specialized and high-quality complements to serve that market better.

Availability of Boundary resources

For developing high quality games, game developers need the right set of tools to take the advantage of each console manufacturer's architecture so that they can produce rich experience for end users. Game development requires a lot of effort and time, here is where game engines comes to rescue for game developers. A game engine is a software tool that provides game developers with a rich set of features to support several core areas of game like audio, video, physics, animation and so on. It helps them build games efficiently and quickly. Boundary resources will be operationalized as the cumulative sum of game engines for platform i in the quarter t. It is a first attempt to study and measure the effect of boundary resources on complementors participation in a platform in the video game industry.

Platform Exclusivity

We capture platform exclusivity as its ability to secure high proportion of exclusive contracts with game developers. A game title is exclusive only if it has been released for only the platform in question and never released on any other rival platform during the time period of observation. It is measured as proportion of exclusive game tiles produced on platform i to total exclusive game titles for all platforms in quarter t. Cennamo and Santaló (2009) used this variable to study effect of exclusivity on hardware demand i.e. platform's market share. Exclusivity is used as a tool to govern complementors in coordinating the development, quality and the release of complementary products (Cennamo & Santaló, 2009). If complementors tends to multi-home and platform firm

has a complex platform architecture, they would prefer to develop complements for rival platforms with less complex architectures (Cennamo et al., 2018).

3.3.3 Moderating Variables

Platform Age

Platform age is measured in months as the difference between date t and the date console i got released. This variable has also been used by scholars in a similar industry setting (Cennamo & Santaló, 2009; Srinivasan & Venkatraman, 2010).

3.3.4 Control Variables

Installed Base

Installed base is measured as cumulative unit sale of console i in the quarter t-1. As with platform age, installed base also has an impact on the indirect network effect and intention of game developers to build games for a platform. Thus, controlling this variable is also important.

Seasonality

The video game sales is highly seasonal in nature. A large number of video game titles gets released in the last quarter of the year. It is in this season that new consoles are also released by platform firms. Thus, it is important to control for this variable as game sales sees a sudden peak in the last quarter of the year. The paper uses a dummy variable for the last quarter of the year.

Existence of New Generations

Whenever a new generation platform is released, consumers are attracted towards the new superior platform. Complementors are then reluctant to support the older generation. One may expect that complementors would start developing game titles for the newer generation as the direct network effects would start decreasing with the introduction of newer generations. This variable is

controlled by introducing a dummy variable for the time-periods in which a console i coexists with a newer generation console. It has also been used as a control variable by Srinivasan and Venkatraman (2010) in their study of network effects in the video game industry

Table 1 will briefly describe all the variables used in the research.

Variables	Measurement
Complementors participation	Proportion of unique game developers for platform i over total game developers in the quarter t
Accessibility to different market	Proportion of game genres produced for platform i over total game genres developed in the quarter t
Availability of Boundary resources	Cummulative sum of game engines released for platform i in the quarter t
Platform Exclusivity	Proportion of exclusive game tiles produced on platform i to total exclusive game titles for all platforms in quarter t
Platform Age	Difference in months between date t and the date console i got released
Installed base	Cumulative unit sale of console i in the quarter t-1
Seasonality	Dummy variable: 1 if the time-period is the last quarter of the year otherwise 0
Existence of new generation	Dummy Variable: 1 if console i coexists with a newer generation otherwise 0

Table 1. Summary of variables in the study

3.4 Method

This chapter lays down the method that will be used to analyze the dataset. The dataset in the study fits the panel data model. A panel data or longitudinal data consists of observations of multiple individuals, industry or events over a series of time periods. In other terms, it can be referred as cross-sectional time series data in which the individual cross-section is being surveyed over different time periods. Panel data observations have two dimensions – the individual cross-section represented by subscript *i* and specific time period represented by subscript *t*. Figure x shows the matrix view of a panel data. A panel data is said to be balanced when the individual cross-section is measured over the same time periods. Otherwise, it is said to be unbalanced. The next section will describe panel data analysis in detail.

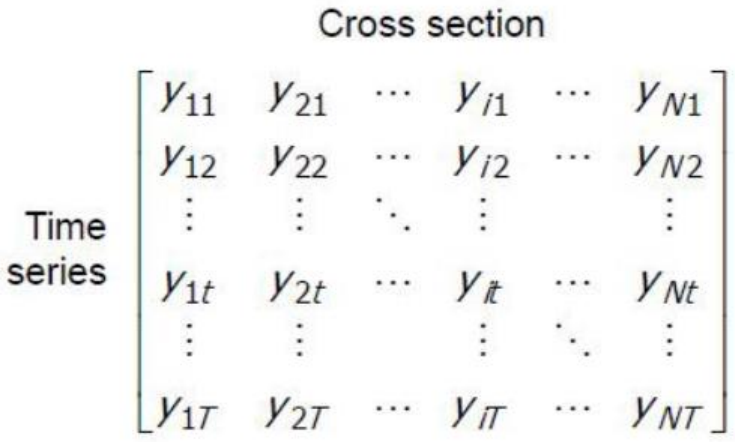


Figure 4. Panel data in matrix form

3.4.1 Panel Data Analysis

Panel data studies have gained traction in the recent years mainly due to the availability of rich data and advances in methodological tools for econometric analysis (Hsiao, 2007). Panel data

allows to account for change in dynamics and can combine differences between and within individual. It provides greater degree of freedom, less collinearity and more variability in the sample to make accurate inferences, thereby making the estimates more efficient (Hsiao, 2007). It also controls for omitted variable bias i.e. it includes the effects of unobserved variables or variables that are not included by the researcher that has correlation with the explanatory variables in the model.

Practically, the simplest way to estimate the model is by pooling all the data and then the researcher can run an ordinary least square regression. These are simple linear regression using panel data and hence called as pooled OLS. A major drawback of this model is that it fails to consider the distinction across individuals and time periods, distorting the true relationships of explanatory variables (Gil-García & Puron-Cid, 2013). In simple words, they fail to capture the individual and temporal effects. The results may be statistically significant with a high R^2 value. However, the estimate may contain auto-correlation among variables leading to misspecification in the model. If this is the case, pooled OLS model may assume that there is a constant intercept as well as constant coefficients. Thus, pooled OLS may mis-specify the model and has high risk of auto-correlation or heteroscedasticity (Park, 2011).

In order to mitigate the above-mentioned issues, scholars devised more advanced econometric panel models that can simultaneously consider heterogeneity at individual level as well as over time. Panel data models can be categorized into fixed effects and random effects model according to their approach to consider the unobserved heterogeneity. Fixed effects model adds dummy variables to the intercepts while the random effects adds dummy variables to the error term (Gil-García & Puron-Cid, 2013). The coefficients for the explanatory variables remain the same across cross-sections or time periods. Simply said, fixed effects model examines the cross-sectional

differences in the intercepts whereas random effects model estimates that cross-sectional differences occur due to the variance in the error terms.

The next section will explain estimation of the fixed effects and the random effect model, the formulas associated with them and the limitations of using each model.

3.4.2 Estimating Fixed Effects Model

Fixed effects model is best suitable for estimating the influence of explanatory variables that varies over time. It examines the relationship between the explanatory variable and the dependent variable within cross-sections. It considers that each cross-section has its own characteristics that may or may not impact the explanatory variable. The basic assumption in fixed effect model is that there are differences in intercepts across cross-sections and these effects are not temporal (time-invariant) (Park, 2011). Thus, the fixed effect model removes the time-invariant effects by controlling for it.

Another assumption that this model makes is that the time-invariant effects are distinct across individuals and should be correlated with one another i.e. it assumes as cross-sections have different characteristics, each individuals error term and intercept should not be correlated. Equation 1 shows the functional form of fixed effects while Equation 2 shows the model after adding (N-1) dummy variables where N is the number of individuals. Since we include a dummy variable in the model, the estimation can be used to specify "differential intercept effect" and hence also called "Least Square Dummy Variable" (LSDV) model.

$$Y_{it} = (\alpha + u_i) + \beta_1 X_{it} + v_{it} \qquad \text{[Equation 1]}$$

Where

- Y_{it} = Dependent variable (DV) (i = individual and t = time period)

- X_{it} = Independent or explanatory variable (IV) (i = individual and t = time period)
- α = intercept
- u_i = Unobserved individual specific effect
- β_1 = Coefficient for Independent variable
- v_{it} = Error term

$$Y_{it} = (\alpha + \alpha_i D_i) + \beta_1 X_{it} + v_{it} \quad \text{[Equation 2]}$$

Where

- Y_{it} = Dependent variable (DV) (i = individual and t = time period)
- X_{it} = Independent or explanatory variable (IV) (i = individual and t = time period)
- α = intercept
- α_i = Intercept for individual i (N-1 dummies are included)
- D_i = Dummy variable for individual i (N-1 dummies are included)
- β_1 = Coefficient for Independent variable
- v_{it} = Error term

We lose a lot of degree of freedom if we estimate fixed effect using LSDV. This is a critical limitation of using LSDV. Fixed effects can also be estimated by dropping the dummy variables. This type of estimator is called the within estimator and uses the mean corrected values of IV and DV. Fixed effects models cannot be used to study time-invariant effects because they are perfectly collinear with the individual (Hsiao, 2007). This can be corrected with the random effect model and is presented in the below section.

3.4.3 Estimating Random Effects Model

The basic rationale behind random effect model is that variance across cross-sections is random and does not have correlation with IVs or DV. According to Greene (2008), an important difference between fixed effect and random effect model is to assume if unobserved individual effects are correlated with the explanatory variables and not if their effects are stochastic. If there is any reason to believe that differences across cross-sections will have some impact on the DV, then a random effect model is best to estimate the effects of the IVs.

An assumption of random effect model is that individual's error term is not correlated with the explanatory variables and this allows to add time-variant variables that can have a role in influencing the explanatory variables. Equation 3 shows the functional form of random effects model.

$$Y_{it} = \alpha + \beta_1 X_{it} + (u_i + v_{it}) \quad \text{[Equation 3]}$$

Where

- Y_{it} = Dependent variable (DV) (i = individual and t = time period)
- X_{it} = Independent or explanatory variable (IV) (i = individual and t = time period)
- α = intercept
- u_i = Unobserved individual specific effect
- β_1 = Coefficient for Independent variable
- v_{it} = Error term

A limitation of random effects model is that the researcher needs to provide the individual characteristics that he thinks to impact the explanatory variables. The problem here is that due to unavailability of those variables, the model will include omitted variable bias (Park, 2011). Table 2 summarizes fixed effects and random effects model. Researcher interest lies in deciding which model to use – fixed effects or the random effects. A fixed effects model can be tested by F-test whereas the random effects model is tested by Breusch and Pagan's Lagrange multiplier (LM) test. The F-test makes a comparison between fixed effects and OLS to check the goodness-of-fit whereas the LM test compares random effects with OLS (Park, 2011). Hausman test can check whether a F-test or LM test fits best to the model by comparing their similarity. In the next section,

Terms	Fixed effect model	Random effect model
Equation	$y_{it} = (\alpha + u_i) + x_{it}\beta + v_{it}$	$y_{it} = \alpha + x_{it}\beta + (u_i + v_{it})$
Intercept	Varying across cross sectional/time series	Constant
Error variance	Constant	Varying across cross sectional/time series
Slope	Constant	Constant
Estimation	Between, Within	FGLS, GLS

Table 2. Fixed effects and random effects panel data model

some basic Stata commands will be presented to estimate panel data in the software.

3.4.4 Basic Stata Commands to estimate panel models

In order to specify panel data, cross-sectional and time-series variables needs to be declared. The Stata command *.xtset* is then followed the cross-sectional and time-series variables. The command can be appended with type of time-series estimation the researcher wants to do - monthly, quarterly or yearly.

.xtset i t, monthly

Where i = cross-section variables and t = time-series variable

To run regression on the panel data, Stata provides the command *.xtreg.* The fixed effect can be run by adding the option "fe" whereas the random effects can be run by adding the option "re". The *.estimate store* saves the results of the regression. To test which model fits best the panel data, the above mentioned hausman test can be performed using the command hausman followed by the fixed effects and random effects regression. The series of commands to do this is described below in figure 5.

```
.xtreg DV IVs, fe
.estimate store fe
.xtreg DV IVs, re
.estimate store re
.hausman fe re
```

Figure 5. Stata commands to test fit between fixed effects and random effects

4. Description of the dataset

The dataset spans two different generation of video game consoles – the seventh and the eighth generation. The seventh generation started in the year 2005 with the introduction of Microsoft's Xbox 360. Just a year later in 2006, Sony's PlayStation 3 and Nintendo's Wii made its launch in the market. In 2012, Nintendo introduced its latest console WiiU which had remarkable technological superiority than the Wii including support for high definition graphics. This embarked the era of the eight generation consoles. Later in 2013, Microsoft and Sony also introduced their successor consoles – Xbox One and PlayStation 4 to give tough competition to Nintendo WiiU. Figure 6 shows quarterly sales figure for the consoles from year 2005 to 2015.

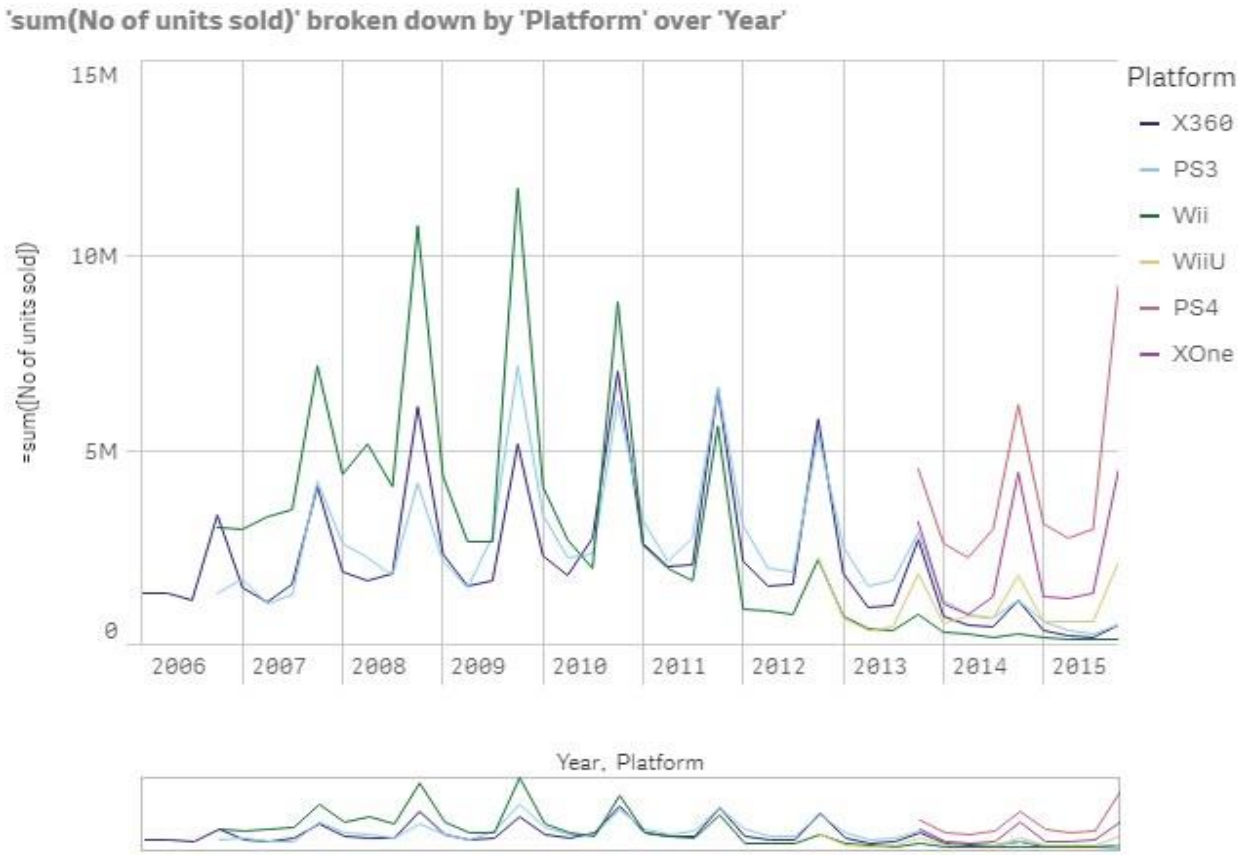


Figure 6. Console sales by Platform over years

Though Xbox 360 was an early entrant, Nintendo Wii established its supremacy since its inception making a record sale of approximately 100 million consoles in the seventh generation. Microsoft and Sony sole approximately 83.1 million and 86.2 million consoles respectively. In the eight generation, Sony leaded the market with 35.93 million consoles sold till 2015 – the last period of our observation. Microsoft and Nintendo sold approximately 18.17 million and 12.27 million consoles till 2015. A common insight from both the generation is that incumbents failed to maintain its leadership and lost to early entrants. By incumbents, we address firms who were early to the market in launching their consoles. The eighth-generation is still in continuation and Microsoft's PlayStation 4 seem to dominate the eighth-generation era.

In the study period of our observation, total of 2199 game titles were released. Table 3 show the top ten game titles per generation. Most of the game titles were released on multiple platforms as well as for different generations. Wii's success in the seventh generation can be attributed to its ability to attract exclusive contracts for its game titles. However, in the seventh generation, top games were mostly released on multiple consoles.

Seventh Generation (PS3/Wii/Xbox 360)		Seventh Generation (PS4/WiiU/Xbox One)	
Game Titles (Platforms)	Sales (Million units)	Game Titles (Platforms)	Sales (Million units)
Wii Sports (Wii)	82,65	Grand Theft Auto V (PS4/Xbox One)	28,11
Grand Theft Auto V (PS3/Xbox 360)	36,18	Call of Duty: Black Ops 3 (PS4/Xbox One)	22,46
Mario Kart Wii (Wii)	35,98	Fallout 4 (PS4/Xbox One)	13,51
Wii Sports Resort (Wii)	32,9	Call of Duty: Advanced Warfare (PS4/Xbox One)	12.75
Wii Play (Wii)	28,92	Star Wars Battlefront (PS4/Xbox One)	12.18
New Super Mario Bros. Wii (Wii)	28,51	Minecraft (PS4/Xbox One)	11.76
Call of Duty: Modern Warfare 3 (PS3/Xbox 360)	28,17	FIFA 16 (PS4/Xbox One)	11,47
Wii Fit (Wii)	22,7	FIFA 15 (PS4/Xbox One)	8.51
Kinect Adventures! (Xbox 360)	22,10	Mario Kart 8 (Wii)	7,69
Wii Fit Plus (Wii)	21,81	The Last of Us Remastered (PS4)	6,77

Table 3. Top ten game titles per generation

The games were spread over a total of 18 genres. Table 4 lists all the genres of the game titles. Figure 7 displays the distribution of game titles grouped by genre. Most of the game titles were released for genre Sports and Action.

List of Genres	
Sports	Adventure
Racing	Music
Sports	Action-Adventure
Misc	Simulation
Platform	Fighting
Party	Strategy
Action	Puzzle
Shooter	MMO
Role-Playing	Visual Novel

Table 4. list of game genres

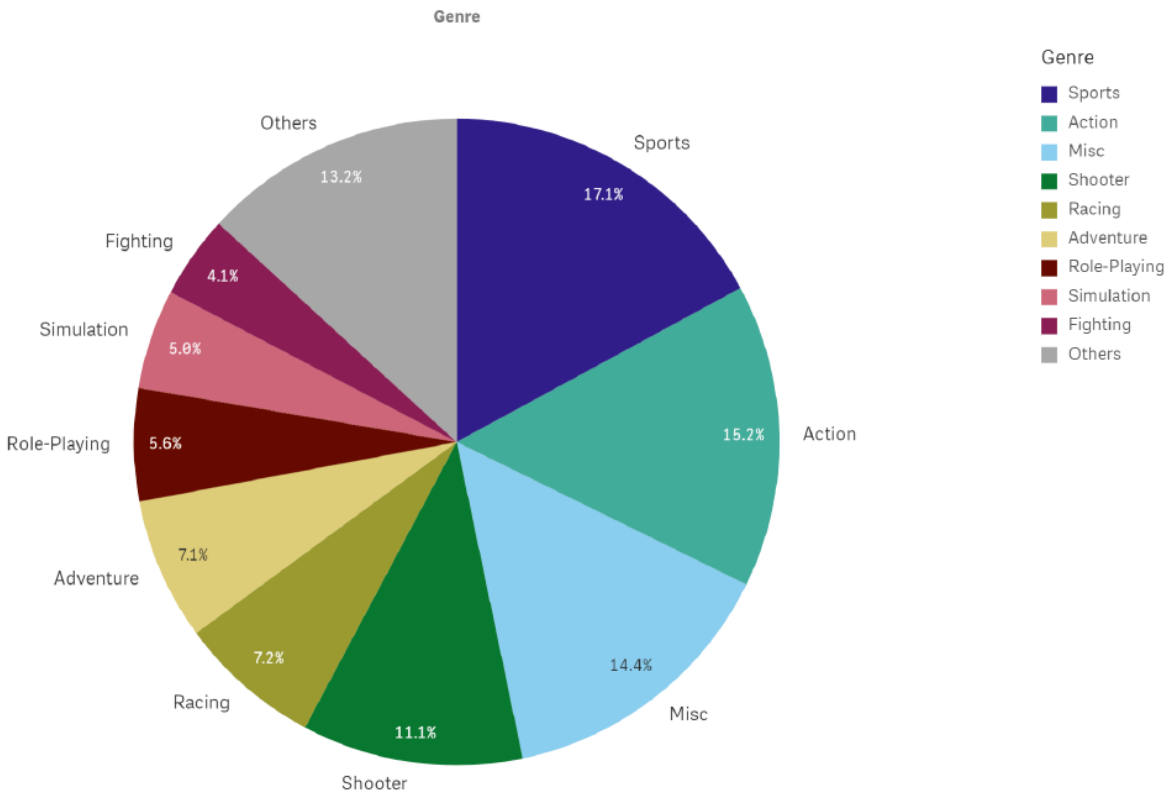


Figure 7. Distribution of game titles by genre

Over the span of 2005-2016, total of 874 developers and 189 publishers were involved in the development of game titles. Figure 8 displays the top 10 developers and publishers according to the number of game titles produced.

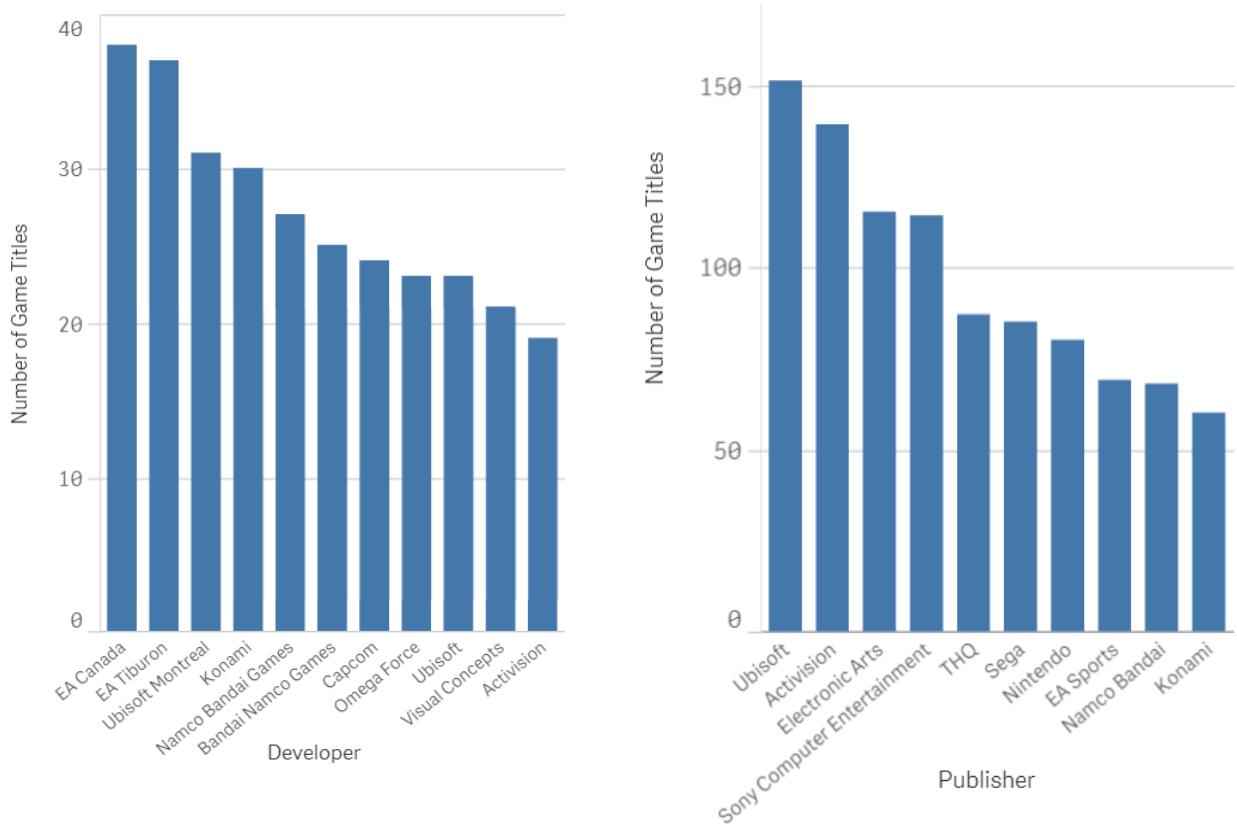


Figure 8. Top 10 game developers and publishers

The success of Nintendo's Wii in the seventh generation can be attributed to its ability to attract a large number of game developers developing games exclusively for the console. This attracted a large number of console users to buy Wii to get access to the premium content that was only available for Wii. Figure 9 graphs the number of exclusive titles released per platform over the years of observation included in our dataset.

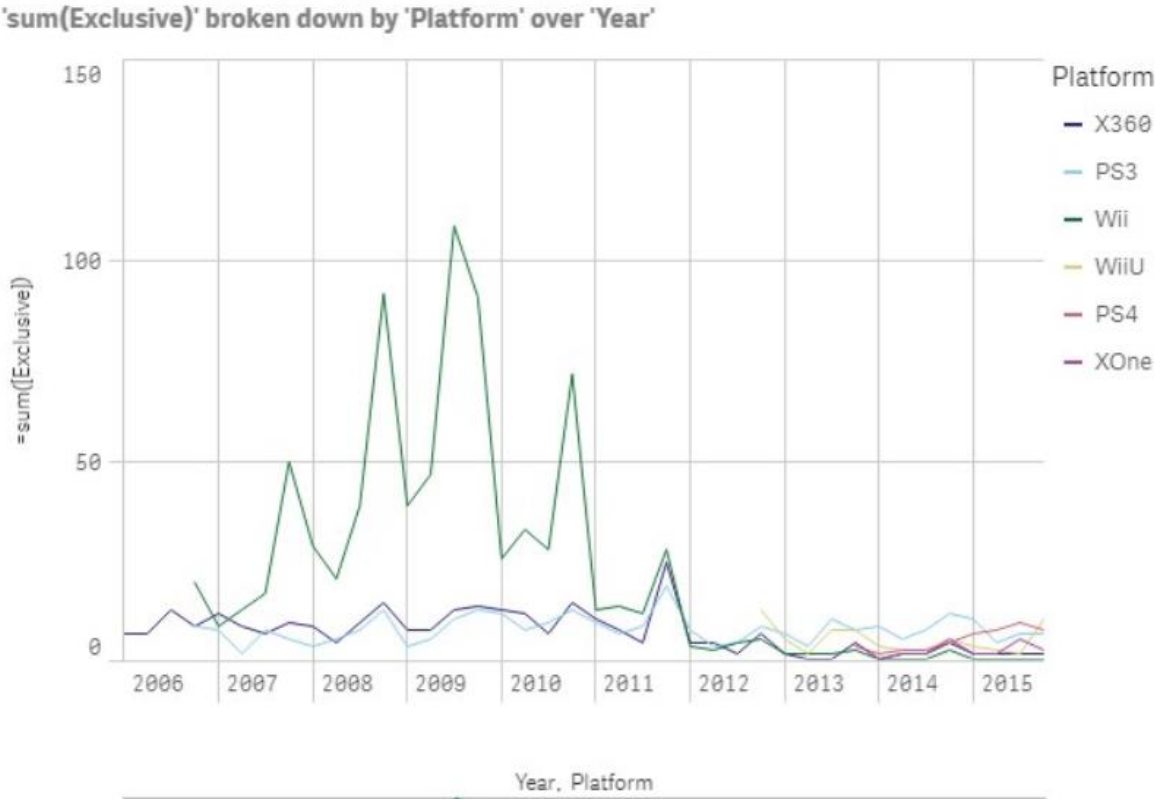


Figure 9. Exclusive game titles released by platform over years

5. Results

The dataset consists of two generations of video game console that were released at different time-periods, making our panel design unbalanced. Table 5 displays basic information about the variables. We have quarterly observations for all the consoles.

variable name	type	format
Console Id	int	%8.0g
Quarter	float	%tq
Platform age	int	%8.0g
Installed base	long	%8.0g
Complementors participation	double	%10.0g
Accessibility to Different Market	double	%10.0g
Platform Exclusivity	double	%10.0g
Availability Boundary Resources	int	%8.0g

Table 5. Description about variables

Table 6 shows the descriptive statistics that shows the correlations between the variables. Table 7 displays the summary statistic of the panel data. *N* value shows that the dataset contains a total observation of 145 (145 quarterly observations). *n* value shows that there is a total of 6 platforms – PS3, Xbox 360, Wii, WiiU, PS4 and Xbox One. T-bar shows the average number of time-periods the platforms were measured. It can be noted that each variable is decomposed into overall, between and within. Overall statistics is estimated with variation over time and cross-sections and is based on 145 observations. Within statistics measure variation over time. In this dataset, it gives summary statistics of 24 time periods irrespective of the platforms. Between statistics measure variation across cross-sections i.e. it shows summary statistics of 6 platforms irrespective of the time-periods. The table also shows the minimum and maximum of each variable used in the analysis.

Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) Accessibility Different Market	1.000				
(2) Availability Boundary Resources	0.276	1.000			
(3) Platform Exclusivity	0.532	-0.280	1.000		
(4) Platform Age	-0.328	0.381	-0.238	1.000	
(5) Installed Base	-0.348	0.158	-0.090	0.926	1.000

Table 6. Pairwise correlations

Variables		Mean	Std. Dev.	Min	Max	Observations
Accessibility Different Market	overall	.643045	.2496355	0	1	N = 145
	between		.1025107	.4779131	.7407045	n = 6
	within		.228955	.1103431	1.110343	T-bar = 24.1667
Availability Boundary Resources	overall	19.12414	7.929273	7	30	N = 145
	between		7.738031	8.384615	25.44444	n = 6
	within		3.639977	5.199138	24.19914	T-bar = 24.1667
Platform Exclusivity	overall	.2758621	.2351759	0	1	N = 145
	between		.0952426	.099528	.3957929	n = 6
	within		.2208287	-.1199308	1.048129	T-bar = 24.1667
Platform Age	overall	48.86897	34.12014	2	119	N = 145
	between		22.97423	13.88889	60.775	n = 6
	within		29.51222	-6.906034	107.094	T-bar = 24.1667
Installed Base	overall	4.40e+07	3.47e+07	0	1.01e+08	N = 145
	between		2.60e+07	5668906	6.83e+07	n = 6
	within		2.79e+07	-2.43e+07	8.28e+07	T-bar = 24.1667

Table 7. Descriptive Statistics

The panel model will take the below form:

$$Y_{it} = \beta_1 Accessibility\ to\ Different\ Market_{it} + \beta_2 Availability\ Boundary\ Resources_{it} + \beta_3 Platform\ Exclusivity_{it} + \beta_4 (Platform\ Exclusivity * Ln(Platform\ Age))_{it} + \beta_5 Ln(Platform\ Age)_{it} + \beta_6 Platform\ Age - Squared_{it} + \beta_7 Installed\ Base_{i(t-1)} + \beta_8 Seasonality_{it} + \beta_9 Existence\ New\ Generation_{it} + \alpha + v_{it}$$

Y_{it} is our dependent variable – complementors participation. Log linear transformation of platform age is used. We also use squared value of platform age due to its curvilinear relationship with the complementors participation as early in the time when platform gets released, it has a small user base and less complementors would be willing to join the platform. As the platform gets matured, complementors participation will increase over time. The same measure has been taken by Srinivasan and Venkatraman (2010) where they use platform age as a moderating variable. Seasonality and existence of new generations are used as dummy variables.

The panel data will be tested to see the fit with fixed effects or random effects model. Hausman test was conducted to check if fixed effects or random effects was the appropriate model for the analysis. Initially the hausman test revealed that some of the coefficients of variables were not on a similar scale. This issue was dealt with scaling the variables causing the issue (Rethemeyer, 2006). Platform Age and installed base was divided by 100000 and 100 respectively. Table 8 shows the results for hausman test after fixing the issues. The null hypothesis of the hausman test says that the coefficients estimated by random effects model are identical to fixed effects model. The p value less than 0.05, so we can reject the null hypothesis and conclude that a fixed effects model should be used to analyze the dataset. Additional diagnostic tests were performed to test the fitness of the model to account for time-fixed effects, autocorrelation, heteroskedasticity and cross-

sectional dependence. The model passed the diagnostic test indicating that no adjustments to be made to the model. Appendix B lays down the type of diagnostic tests along with their results.

Hausman (1978) specification test

	Coef.
Chi-square test value	21.812
P-value	.009

Table 8. Results of hausman test

Table 9 shows the estimation for the fixed effects panel data model. Model 1 only includes the control variables. In Model 2, two variables - accessibility to different market and availability of boundary resources were introduced including the control variables. It shows that accessibility to different market has a positive influence on complementors participation. In Model 3, only the independent variables are included. Without controlling for any variables, each of the independent variables has a significant and positive influence on complementors participation except the interaction variable between platform exclusivity and platform age. In Model 4, platform exclusivity is introduced along with the control variables. It can be seen that platform exclusivity has a positive influence on complementors participation. In Model 5, we include all the independent variables with the control variables. If we compare the R-squared value of all the models, Model 5 has the highest adjusted R-squared values which means the Model 5 best fits suits our estimation of the coefficients. Appendix B shows the extended regression results for Model 5.

Hypothesis 1 states that accessibility to different market will have a positive impact on complementors participation. The coefficient is 0.134 with $p<0.05$ indicating that p-value is low enough to reject the null hypothesis. So, hypothesis 1 is accepted.

Hypothesis 2 states that availability of boundary resources has a positive relationship with complementors participation in a platform. The coefficient value is 0.01 with $p<0.01$ indicating that it is small enough to reject the null hypothesis. This is consistent with the theoretical model and hypothesis 2 is accepted.

Hypothesis 3A states that exclusivity has a positive impact on complementors participation in a platform. The coefficient is 1.209 with $p<0.01$ showing a positive relationship with complementors participation. This matches with the theoretical model and hypothesis 3 is accepted.

Hypothesis 3B tests the influence of platform age as a moderating variable. The moderating effect of platform age measured as the interaction between platform exclusivity and platform age has a coefficient of -0.168 with $p<0.01$. The negative coefficient points out that the influence of platform exclusivity on complementors participation decreases with platform age. Hypothesis 3B is also accepted. Due to increased intra platform competition in older platforms, complementors does not deem exclusivity as an important strategy to appropriate rents rather they develop for multiple platforms to appease a large mass of consumers.

Complementors Participation	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5
Ln(Platform Age)	-0.0187	-0.0222		0.00915	0.0478**
	(0.0349)	(0.0268)		(0.0172)	(0.0182)
Platform Age Squared (100)	-0.000510	0.00225		0.000263	-0.00106
	(0.00140)	(0.00116)		(0.000749)	(0.000759)
Installed Base(1000000)	0.00191	0.00190		0.000996	0.00209**
	(0.00169)	(0.00120)		(0.000768)	(0.000757)
Existence New Generation	-0.262***	-0.171**		-0.125***	-0.121***
	(0.0747)	(0.0569)		(0.0364)	(0.0340)
Seasonality	0.00946	-0.0733**		0.00486	0.00966
	(0.0333)	(0.0246)		(0.0166)	(0.0156)
Accessibility to Different Market		0.742***	0.202***	0.167**	0.134*
		(0.0562)	(0.0677)	(0.0430)	(0.0596)
Availability Boundary Resources		-0.00903	0.00915***	0.00434	0.0100**
		(0.00549)	(0.00264)	(0.00362)	(0.00362)
Platform Exclusivity			0.713***	0.649***	1.209***
			(0.105)	(0.0465)	(0.132)
Platform Exclusivity* Ln(Platform Age)			-0.0192		-0.168***
			(0.0292)		(0.0374)
Constant	0.475***	0.0895	-0.0616	-0.00732	-0.233**
	(0.0861)	(0.0817)	(0.0546)	(0.0524)	(0.0703)
Observations	145	145	145	145	145
Adjusted R-squared	0.171	0.583	0.807	0.831	0.853

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 9. Estimation of Fixed Effects Model

6. Discussions

This paper mainly contributes to the understanding of the design and government aspects of platforms that influences complementors participation in a platform. Scholars have tried to study specific aspects of design and governance strategies used by platform firms and their influence on platform dominance (Cho et al., 2014; Corts & Lederman, 2009; Ondrus, Gannamaneni, & Lyytinen, 2015). Previous studies have ignored the view of complementors and treated them as exogenously available (McIntyre & Srinivasan, 2017). With some exceptions where scholars have tried to study factors that influences complementor's intention to stick to a platform (Choi et al., 2017; Schaarschmidt et al., 2019). However, previous studies lacked to generalize its finding in an industry context and failed to develop a model that includes different aspects of platform design and governance. This paper highlights the importance of design and governance strategies that platform firms can use to strategically orchestrate a large network of complementors. This paper also attempts to explain the influence of decisions taken by platform firms to design and govern its platform on complementors participation. The academic and managerial relevance of the study is presented as follows.

6.1 Academic Relevance

This thesis extends the open-platform literature by introducing a new dimension on how complementors perceive and measure platform openness. Platform openness seems to play a significant role in shaping competition within its complementors. Complementors may be reluctant to participate in a platform that has intense competition despite the fact that an open platform can give easy access to the core technology and the installed base of its users. This shows that platform openness cannot alone be studied as design aspect of platform where it merely means

sharing the core architecture of the platform to produce differentiated products for the end-users. It also embodies governance aspects where platform firms shape competition and controls the behavior of the complementors. When a firm pursue a high degree of openness, it should try to smoothen competition between its complementors. The first hypothesis highlights the importance of vertically opening the platform to different markets. Access to a wider market will smoothen competition as well as attract complementors due to a wider consumer base they can reach. Its effect can be empirically seen in the video game industry where a platform that supports game titles spanning a variety of genres has a positive influence on complementors participation. Nintendo's Wii was successful in attracting complementors to develop 1013 unique game titles spanning over 15 genres in the time period of the study and prove its dominance in the 7th generation consoles.

A distinct contribution of this paper to the engineering design literature is to quantify and measure platform boundary resources which have mostly been studied in qualitative terms (Ghazawneh & Henfridsson, 2013; Karhu et al., 2018). The second hypothesis emphasized the positive effect of platform boundary resources on complementors participation. The analysis controlled for platform age as one would expect that the number of boundary resources increases as the platform matures. Whether it be an open or a closed platform, the results reinforces the importance of boundary resources in attracting a large number of complementors to participate in the platform ecosystem. Boundary resources have become a critical aspect in the decision of a complementor to join a platform. Complementors invest their efforts in producing complements for the platform. Platform owners can strategically gain competitive advantage over it rivals by providing resources that can ease the development and commercialization of their products.

Another interesting contribution of this paper is to explain when an exclusive contract may be promising for complementors. This is done by introducing platform age as a moderating variable. In an industry where a consumer prefers to own a "must have complement", complementors can appropriate high rents by exercising their power to reduce royalties charged by platform firms in exchange for exclusive contents. The empirical result suggests that exclusivity has a positive effect on complementors participation. But when does it make sense for a complementor to enter into an exclusive contract? When a platform is in its early stages, the environment is favorable for complementors since they have reduced competition and can make profits selling exclusive contents. As platform matures and its installed base increases, competition between complementors also spurges. This disincentivizes complementors to develop exclusively for the platform. Rather, complementors can benefit by selling the complement on multiple platforms due to its ability to reach the installed base of rival platforms. The benefits of multi-homing then outweigh the exclusive rents, complementors can appropriate if they were to develop just for one platform. The results also provided empirical evidence that the impact of exclusivity on complementors participation decreases with platform age.

6.2 Managerial Relevance

These results also have crucial managerial relevance. It presents deeper understanding of factors that complementors deem important in their decision to participate in the platform ecosystem. By opening the platform to diverse markets and smoothening competition between complementors, platform firms can efficiently accrue the benefits of network effects. However, at the same time they would face strategic tradeoff to increase diversity or quality. In a platform with increased competition, quality of complements tends to be high. It would be worthwhile for managers to focus into strategies that would help them control the quality of complements while at the same

time opening the platform to a large number of complementors by providing access to diverse markets. Platform firms can govern complementors and the quality of complements through boundary resources. Managers should focus on incentivizing complementors by providing them with appropriate tools that not only ease their development but provide them architectural capabilities to produce high quality complements. Interesting implications to be studied further could be the impact of boundary resources on the quality of complements and complementor's performance. Another interesting extension could be to understand the effect of boundary resources for small and big complementors. Small complementors may deem the presence of boundary resources as highly important since they do not possess the resources and finances to build its own boundary resource from scratch. The same may be different for big complementors who can invest heavily into building the resources it needs.

The above results also have important managerial implications for early entrants and incumbents. For early entrants, availability of high-quality exclusive contents helps them distinguish its platform from the incumbents. Complementors are likely to be in exclusive contract in the early stages of the platforms. By securing exclusive agreements, early entrants can breakthrough into the market and attract a large mass of consumers. The question for incumbents then is to how they can still incentivize complementors to develop exclusively for their platform when complementors tend to multi-home in the mature stages.

7. Conclusion and Limitations

This study attempts to take complementor's perspective in explaining the effects of design and governance strategies adopted by platform firms on the decision of complementors to participate in a platform. Accessibility to different markets and availability of boundary resources are seen to have positive effects on complementors participation. Exclusivity seems to be favorable for complementors in the early stages of the platform since they can appropriate high rents from the platform firms. However, as the platform matures increased competition decreases incentives to contract exclusively and complementors tends to multi-home.

The findings in this study opens interesting avenues for future research that provides directions to extend and refine the research model and address the limitations in the research.

1. Firstly, we should be cautious to generalize our findings beyond the video game industry. The video game industry consists of multiple incompatible rival platforms leading to more intense inter-platform competition. Also, only a few complementary products reach the "hit-status" and contributes to the maximum games sales. This also indicates a high competition among complementors to deliver high quality content. This may not be the case in industries where very few competing platforms operate, and quality of the complements are homogenous. For example, in an environment with less competition like iOS and Android, they compete to ensemble a large installed base of user. This can be achieved by encompassing a large number of complements and exclusivity may not be important in this case. This means that the impact of the factors in the study can be different in different industry settings. Future studies should validate whether the findings in this research can be generalized to other industry settings.

2. Further studies can include more factors related to design and governance of platforms and extend the research model. It would be interesting to quantify the influence of platform architectural elements such as modularity and compatibility on complementors participation. It is also worthwhile to study the implications of revenue sharing between platform firms and complementors on complementor's decision to participate in a platform. Another aspect of complementor competition can be seen as platform firms entering the complementary product space. It would be interesting to see how platform owner's entry into the complementary product market influences complementors participation in a platform.
3. This study is distinct in the way that it is one of the first to measure platform boundary resources. However, due to the nature of the industry, it was difficult to obtain information about the game engines used by game developers to develop game titles. Future studies could use more detailed and fine-grained approach to measure and operationalize platform boundary resources.

References

Anvaari, M., & Jansen, S. (2010, 2010). *Evaluating architectural openness in mobile software platforms.* Paper presented at the the Fourth European Conference.

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics, 37*(3), 668-691. doi:10.1111/j.1756-2171.2006.tb00037.x

Armstrong, M., & Wright, J. (2006). Two-sided Markets, Competitive Bottlenecks and Exclusive Contracts. *Economic Theory, 32*(2), 353-380. doi:10.1007/s00199-006-0114-6

Bakos, Y., & Katsamakas, E. (2014). Design and Ownership of Two-Sided Networks: Implications for Internet Platforms. *Journal of Management Information Systems, 25*(2), 171-202. doi:10.2753/mis0742-1222250208

Benlian, A., Hilkert, D., & Hess, T. (2015). How open is this Platform? The Meaning and Measurement of Platform Openness from the Complementers' Perspective. *Journal of Information Technology, 30*(3), 209-228. doi:10.1057/jit.2015.6

Bianco, V. D., Myllarniemi, V., Komssi, M., & Raatikainen, M. (2014). *The Role of Platform Boundary Resources in Software Ecosystems: A Case Study*. Paper presented at the 2014 IEEE/IFIP Conference on Software Architecture.

Boudreau, K. (2010). Open Platform Strategies and Innovation: Granting Access vs. Devolving Control. *Management Science, 56*(10), 1849-1872. doi:10.1287/mnsc.1100.1215

Carrillo, J. D., & Tan, G. (2015). Platform Competition with Complementary Products. 44.

Cennamo, C., Ozalp, H., & Kretschmer, T. (2018). Platform Architecture and Quality Trade-offs of Multihoming Complements. *Information Systems Research, 29*(2), 461-478. doi:10.1287/isre.2018.0779

Cennamo, C., & Santaló, J. (2009). Intra-Platform Competition, Exclusivity and Dissimilarity Strategies in the Videogame Industry. *SSRN Electronic Journal*. doi:10.2139/ssrn.1540131

Chakravorti, S., & Roson, R. (2006). Platform Competition in Two-Sided Markets: The Case of Payment Networks. *Review of Network Economics*(1), 25.

Cho, D., Kumar, A., & Telang, R. (2014). The Impact of iPhone Exclusivity Arrangement on Demand for Smartphones. *SSRN Electronic Journal*. doi:10.2139/ssrn.2468048

Choi, G., Nam, C., & Kim, S. (2017). The Impacts of Mobile Platform Openness on Application Developers' Intention to Continuously Use a Platform: From an Ecosystem Perspective. 28.

Chowdhury, S. M., & Martin, S. (2016). Exclusivity and exclusion on platform Markets. *Journal of Economics, 120*(2), 95-118. doi:10.1007/s00712-016-0499-z

Corts, K. S., & Lederman, M. (2009). Software exclusivity and the scope of indirect network effects in the U.S. home video game market. *International Journal of Industrial Organization, 27*(2), 121-136. doi:10.1016/j.ijindorg.2008.08.002

Cusumano, M. A., & Gawer, A. (2003). The elements of platform leadership. *IEEE Engineering Management Review, 31*(1), 8-8. doi:10.1109/EMR.2003.1201437

de Reuver, M., Sørensen, C., & Basole, R. C. (2018). The Digital Platform: A Research Agenda. *Journal of Information Technology, 33*(2), 124-135. doi:10.1057/s41265-016-0033-3

Eaton, B., Elaluf-Calderwood, S., Sørensen, C., & Yoo, Y. (2015). Distributed Tuning of Boundary Resources: The Case of Apple's iOS Service System. *MIS Quarterly, 39*(1), 217-243. doi:10.25300/MISQ/2015/39.1.10

Eisenmann, T. R., Parker, G., & Alstyne, M. V. (2010). Platform Envelopment. 23.

Eisenmann, T. R., Parker, G., & Van Alstyne, M. W. (2008). *Opening Platforms: How, When and Why?* (ID 1264012). Retrieved from Rochester, NY: https://papers.ssrn.com/abstract=1264012

files/458/papers.html

Evans, D. S. (2009). *Two-Sided Market Definition* (ID 1396751). Retrieved from Rochester, NY: https://papers.ssrn.com/abstract=1396751

files/452/papers.html

Fennell, M. L., & Alexander, J. A. (1987). Organizational Boundary Spanning in Institutionalized Environments. *The Academy of Management Journal*, *30*(3), 456-476. doi:10.2307/256009

Filistrucchi, L., Geradin, D., van Damme, E., & Affeldt, P. (2014). Market Definition in Two-Sided Markets: Theory and Practice. *Journal of Competition Law and Economics*, *10*(2), 293-339. doi:10.1093/joclec/nhu007

Gawer, A. (2009). *Platforms, markets, and innovation* (A. Gawer Ed.). Cheltenham, UK ; Northampton, MA: Edward Elgar.

Gawer, A. (2014). Bridging differing perspectives on technological platforms: Toward an integrative framework. *Research Policy*, *43*(7), 1239-1249. doi:10.1016/j.respol.2014.03.006

Ghazawneh, A., & Henfridsson, O. (2010, 2010). *Governing third-party developement through platform boundary resources.* Paper presented at the International Conference on Information Systems.

Ghazawneh, A., & Henfridsson, O. (2013). Balancing platform control and external contribution in third-party development: the boundary resources model. *Information Systems Journal*, *23*(2), 173-192. doi:10.1111/j.1365-2575.2012.00406.x

Gil-García, J. R., & Puron-Cid, G. (2013). Using Panel Data Techniques for Social Science Research: an Illustrative Case and Some Guidelines.

Gil, R., & Warzynski, F. (2015). Vertical Integration, Exclusivity, and Game Sales Performance in the US Video Game Industry. *Journal of Law, Economics, and Organization, 31*(suppl 1), i143-i168. doi:10.1093/jleo/ewu006

Greene, W. H. (2008). *Econometric Analysis*: Pearson.

Hagiu, A. (2005, 2005). Pricing and Commitment by Two-Sided Platforms.

Hagiu, A., & Lee, R. S. (2011). Exclusivity and Control. *Journal of Economics & Management Strategy, 20*(3), 679-708. doi:10.1111/j.1530-9134.2011.00302.x

Halman, J. I. M., Hofer, A. P., & van Vuuren, W. (2003). Platform-Driven Development of Product Families: Linking Theory with Practice. *Journal of Product Innovation Management, 20*(2), 149-162. doi:10.1111/1540-5885.2002007

Hsiao, C. (2007). Panel data analysis—advantages and challenges. *TEST*. doi:http://dx.doi.org/10.1007/s11749-007-0046-x.

Isckia, T., de Reuver, M., & Lescop, D. (2018). *Digital innovation in platform-based ecosystems*. Paper presented at the Proceedings of the 10th International Conference on Management of Digital EcoSystems - MEDES '18.

Jacobides, M. G., Cennamo, C., & Gawer, A. (2018). Towards a theory of ecosystems. *Strategic Management Journal, 39*(8), 2255-2276. doi:10.1002/smj.2904

Karhu, K., Gustafsson, R., & Lyytinen, K. (2018). Exploiting and Defending Open Digital Platforms with Boundary Resources: Android's Five Platform Forks. *Information Systems Research, 29*(2), 479-497. doi:10.1287/isre.2018.0786

Katz, M. L., & Shapiro, C. (1985). Network Externalities, Competition, and Compatibility. *The American Economic Review, 75*(3), 424-440.

Koch, S., & Kerschbaum, M. (2014). Joining a smartphone ecosystem: Application developers' motivations and decision criteria. *Information and Software Technology, 56*(11), 1423-1435. doi:10.1016/j.infsof.2014.03.010

Lee, R. S. (2013). Vertical Integration and Exclusivity in Platform and Two-Sided Markets. *American Economic Review, 103*(7), 2960-3000. doi:10.1257/aer.103.7.2960

Mantena, R., Sankaranarayanan, R., & Viswanathan, S. (2010). Platform-based information goods: The economics of exclusivity. *Decision Support Systems, 50*(1), 79-92. doi:10.1016/j.dss.2010.07.004

Martin, M. V., & Ishii, K. (2002). Design for variety: developing standardized and modularized product platform architectures. *Research in Engineering Design, 13*(4), 213-235. doi:10.1007/s00163-002-0020-2

McIntyre, D. P., & Srinivasan, A. (2017). Networks, platforms, and strategy: Emerging views and next steps: Networks, Platforms, and Strategy. *Strategic Management Journal, 38*(1), 141-160. doi:10.1002/smj.2596

Mukhopadhyay, S., de Reuver, M., & Bouwman, H. (2016). Effectiveness of control mechanisms in mobile platform ecosystem. *Telematics and Informatics, 33*(3), 848-859. doi:10.1016/j.tele.2015.12.008

Ondrus, J., Gannamaneni, A., & Lyytinen, K. (2015). The Impact of Openness on the Market Potential of Multi-Sided Platforms: A Case Study of Mobile Payment Platforms. *Journal of Information Technology, 30*(3), 260-275. doi:10.1057/jit.2015.7

Papachristos, G., & Van De Kaa, G. (2016). Platform competition processes: A future research outlook. *Conference Proceedings*, 23.

Park, H. M. (2011). Practical Guides To Panel Data Modeling: A Step by Step

Analysis Using Stata. http://www.iuj.ac.jp/faculty/kucc625

Parker, G., & Van Alstyne, M. (2008). Managing Platform Ecosystems. *ICIS 2008 Proceedings. 53.*

Rethemeyer, R. K. (2006). *PAD 705 Handout: Panel Data*. Retrieved from Rockefeller College - University at Albany

Schaarschmidt, M., Homscheid, D., & Kilian, T. (2019). Application developer engagement in open software platforms: An empirical study of Apple IOS and Google Android developers. *23*(04), 1950033. doi:10.1142/s1363919619500336

Scholten, S., & Scholten, U. (2011). Platform-based Innovation Management: Directing External Innovational Efforts in Platform Ecosystems. *Journal of the Knowledge Economy*, *3*(2), 164-184. doi:10.1007/s13132-011-0072-5

Schreieck, M., Wiesche, M., & Krcmar, H. (2016). Design and governance of platform ecosystems – Key concepts and issues for future research. 21.

Setzke, D. S., Böhm, M., & Krcmar, H. (2019). *Platform Openness: A Systematic Literature Review and Avenues for Future Research*. Paper presented at the 14th International Conference on Wirtschaftsinformatik, Siegen, Germany. https://www.researchgate.net/publication/331383281_Platform_Openness_A_Systematic_Literature_Review_and_Avenues_for_Future_Research

Smedlund, A., & Faghankhani, H. (2015). *Platform Orchestration for Efficiency, Development, and Innovation*. Paper presented at the 2015 48th Hawaii International Conference on System Sciences.

Srinivasan, A., & Venkatraman, N. (2010). Indirect Network Effects and Platform Dominance in the Video Game Industry: A Network Perspective. *IEEE Transactions on Engineering Management, 57*(4), 661-673. doi:10.1109/tem.2009.2037738

Statista. (2019). *Global video games market value from 2012 to 2021*. Retrieved from https://www.statista.com/statistics/246888/value-of-the-global-video-game-market/

files/502/value-of-the-global-video-game-market.html

Termeer, C. J. A. M., & Bruinsma, A. (2016). ICT-enabled boundary spanning arrangements in collaborative sustainability governance. *Current Opinion in Environmental Sustainability, 18*, 91-98. doi:10.1016/j.cosust.2015.11.008

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Research Commentary —Platform Evolution: Coevolution of Platform Architecture, Governance, and Environmental Dynamics. *Information Systems Research, 21*(4), 675-687. doi:10.1287/isre.1100.0323

van de Kaa, G., & de Vries, H. J. (2015). Factors for winning format battles: A comparative case study. *Technological Forecasting and Social Change, 91*, 222-235. doi:10.1016/j.techfore.2014.02.019

van de Kaa, G., de Vries, H. J., & Rezaei, J. (2014). Platform selection for complex systems: Building automation systems. *Journal of Systems Science and Systems Engineering, 23*(4), 415-438. doi:10.1007/s11518-014-5258-5

West, J. (2003). How open is open enough? *Research Policy, 32*(7), 1259-1285. doi:10.1016/s0048-7333(03)00052-0

Yang, C., & Jiang, S. (2006). Strategies for Technology Platforms. *Research-Technology Management, 49*(3), 48-57. doi:10.1080/08956308.2006.11657378

Appendix A: Extended Regression results for Model 3

Table 10 displays the extended regression results for model 3 which includes the standard error and t-values. Model 3 consists of all the variables used in the conceptual model.

Regression results

Complementors Participation	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Accessibility to Different Markets	0.134	0.056	2.38	0.019	0.023	0.245	**
Platform Exclusivity	1.209	0.132	9.15	0.000	0.948	1.471	***
Platform Exclusivity * Ln(Age)	-0.168	0.037	-4.49	0.000	-0.241	-0.094	***
Availability Boundary resources	0.010	0.004	2.78	0.006	0.003	0.017	***
Ln(Platform Age)	0.048	0.018	2.62	0.010	0.012	0.084	**
Platform Age(100)	-0.001	0.001	-1.40	0.164	-0.003	0.000	
Installed Base(1000000)	0.002	0.001	2.76	0.007	0.001	0.004	***
Existence New Generation	-0.121	0.034	-3.55	0.001	-0.188	-0.053	***
Seasonality	0.010	0.016	0.62	0.536	-0.021	0.041	
Constant	-0.233	0.070	-3.32	0.001	-0.372	-0.094	***

Mean dependent var	0.422	SD dependent var	0.210
R-squared	0.867	Number of obs	145.000
F-test	94.221	Prob > F	0.000
Akaike crit. (AIC)	-337.167	Bayesian crit. (BIC)	-307.400

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10. Extended fixed effects regression results

Appendix B: Diagnostic tests on panel data

Some diagnostics tests were applied on the model to check for serial time-fixed effects, cross-dependence, heteroskedasticity and serial autocorrelation. After interpreting the results of the tests, it was concluded that the model did not need any adjustments and the regression results are reliable.

Test 1: Test for time-fixed effects

To check if a time-fixed effects need to be included when estimating the fixed effects results, the Stata command tesparm was run. This command tests if the time dummies for all the periods in the study are equal to zero. For executing this command, the regression is run first with the time dummies included. After that the command tesparm i.Quarter is run. Table 11 shows the fixed

effect regression results with time dummies included. Table 12 shows the results of tesparm command. The value for Prob>F is 0.7336. This indicated that we fail to reject the null hypothesis. Therefore, there is no time-fixed effects.

Regression results

Complementors participation	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Accessibility to Different Market	0.198	0.079	2.51	0.014	0.041	0.355	**
Platform Exclusivity	1.182	0.260	4.55	0.000	0.666	1.698	***
Platform Exclusivity *Ln(Age)	-0.167	0.064	-2.59	0.011	-0.295	-0.039	**
Availability Boundary resources	0.007	0.007	1.02	0.309	-0.007	0.021	
Ln(Platform Age)	0.079	0.043	1.84	0.069	-0.006	0.164	*
Platform Age(100)	0.000	0.002	-0.16	0.875	-0.005	0.004	
Installed B~1000000)	0.001	0.002	0.24	0.810	-0.004	0.005	
Existence New Generation launch	-0.088	0.047	-1.86	0.066	-0.182	0.006	*
Seasonality	-0.007	0.516	-0.01	0.989	-1.031	1.017	
Quarterly							
185.Quarterly	0.027	0.114	0.23	0.815	-0.199	0.253	
186.Quarterly	0.047	0.123	0.38	0.702	-0.197	0.292	
187.Quarterly	0.054	0.452	0.12	0.906	-0.844	0.952	
188.Quarterly	0.067	0.164	0.41	0.683	-0.259	0.394	
189.Quarterly	0.040	0.175	0.23	0.821	-0.308	0.388	
190.Quarterly	-0.029	0.188	-0.15	0.877	-0.403	0.344	
191.Quarterly	0.046	0.387	0.12	0.906	-0.723	0.814	
192.Quarterly	0.050	0.202	0.25	0.805	-0.352	0.452	
193.Quarterly	0.042	0.213	0.20	0.843	-0.381	0.465	
194.Quarterly	0.032	0.222	0.14	0.885	-0.410	0.474	
195.Quarterly	0.008	0.339	0.02	0.981	-0.664	0.681	
196.Quarterly	-0.016	0.240	-0.07	0.947	-0.492	0.460	
197.Quarterly	0.012	0.247	0.05	0.962	-0.478	0.501	
198.Quarterly	-0.002	0.254	-0.01	0.992	-0.506	0.501	
199.Quarterly	0.054	0.299	0.18	0.856	-0.540	0.649	
200.Quarterly	-0.042	0.273	-0.15	0.879	-0.584	0.501	
201.Quarterly	-0.003	0.281	-0.01	0.992	-0.562	0.556	
202.Quarterly	0.001	0.292	0.01	0.996	-0.578	0.581	
203.Quarterly	0.060	0.254	0.24	0.814	-0.444	0.564	
204.Quarterly	0.062	0.312	0.20	0.842	-0.557	0.681	
205.Quarterly	0.020	0.321	0.06	0.951	-0.618	0.658	
206.Quarterly	0.053	0.329	0.16	0.873	-0.601	0.706	
207.Quarterly	0.068	0.207	0.33	0.744	-0.344	0.479	
208.Quarterly	0.104	0.358	0.29	0.773	-0.607	0.814	
209.Quarterly	0.106	0.367	0.29	0.773	-0.623	0.835	
210.Quarterly	0.106	0.375	0.28	0.777	-0.639	0.852	
211.Quarterly	0.034	0.162	0.21	0.834	-0.288	0.356	
212.Quarterly	0.041	0.399	0.10	0.918	-0.751	0.833	
213.Quarterly	0.086	0.412	0.21	0.835	-0.731	0.904	
214.Quarterly	0.044	0.421	0.10	0.918	-0.793	0.880	
215.Quarterly	0.038	0.113	0.34	0.734	-0.186	0.263	
216.Quarterly	-0.005	0.447	-0.01	0.991	-0.893	0.883	
217.Quarterly	0.111	0.456	0.24	0.808	-0.795	1.018	
218.Quarterly	0.019	0.467	0.04	0.968	-0.908	0.945	
219.Quarterly	0.032	0.064	0.50	0.618	-0.095	0.159	
220.Quarterly	-0.050	0.487	-0.10	0.918	-1.018	0.917	
221.Quarterly	-0.026	0.496	-0.05	0.958	-1.012	0.959	
222.Quarterly	0.023	0.506	0.04	0.964	-0.981	1.027	
Constant	-0.310	0.180	-1.72	0.088	-0.667	0.047	*

Mean dependent var	0.422	SD dependent var	0.210
R-squared	0.901	Number of obs	145.000
F-test	17.831	Prob > F	0.000

Table 11. Regression results with time-fixed effects

```
( 1)  185.Quarterly = 0
 ( 2)  186.Quarterly = 0
 ( 3)  187.Quarterly = 0
 ( 4)  188.Quarterly = 0
 ( 5)  189.Quarterly = 0
 ( 6)  190.Quarterly = 0
 ( 7)  191.Quarterly = 0
 ( 8)  192.Quarterly = 0
 ( 9)  193.Quarterly = 0
 (10)  194.Quarterly = 0
 (11)  195.Quarterly = 0
 (12)  196.Quarterly = 0
 (13)  197.Quarterly = 0
 (14)  198.Quarterly = 0
 (15)  199.Quarterly = 0
 (16)  200.Quarterly = 0
 (17)  201.Quarterly = 0
 (18)  202.Quarterly = 0
 (19)  203.Quarterly = 0
 (20)  204.Quarterly = 0
 (21)  205.Quarterly = 0
 (22)  206.Quarterly = 0
 (23)  207.Quarterly = 0
 (24)  208.Quarterly = 0
 (25)  209.Quarterly = 0
 (26)  210.Quarterly = 0
 (27)  211.Quarterly = 0
 (28)  212.Quarterly = 0
 (29)  213.Quarterly = 0
 (30)  214.Quarterly = 0
 (31)  215.Quarterly = 0
 (32)  216.Quarterly = 0
 (33)  217.Quarterly = 0
 (34)  218.Quarterly = 0
 (35)  219.Quarterly = 0
 (36)  220.Quarterly = 0
 (37)  221.Quarterly = 0
 (38)  222.Quarterly = 0
       F( 38,    92) =    0.83
            Prob > F =    0.7336
```

Table 12 Output for tesparm command

Test 2: Test for cross-sectional dependence and heteroskedasticity

Next the model was tested for the presence of cross-sectional dependence. The Breusch-Pagan LM test indicates if the residuals across the cross-sections are not correlated. The Stata command xttest2 is used to achieve this. Heteroskedasticity was tested using the Stata command xttest3. Table 13 and table 14 shows the results of cross-sectional dependence and heteroskedasticity tests respectively. Again, we failed to reject the null hypothesis for both the tests. Therefore, there was no presence of cross-sectional dependence and heteroskedasticity.

Correlation matrix of residuals:

	__e1	__e2	__e3	__e4	__e5	__e6
__e1	1.0000					
__e2	0.1377	1.0000				
__e3	-0.0010	-0.2321	1.0000			
__e4	0.7418	-0.1212	-0.1382	1.0000		
__e5	0.6789	-0.2915	0.0376	0.6728	1.0000	
__e6	-0.2175	0.0551	0.4250	0.0258	0.1399	1.0000

Breusch-Pagan LM test of independence: chi2(15) = **17.173**, Pr = **0.3086**
Based on 9 complete observations over panel units

Table 13. Results for xttest2 (Breusch-Pagan LM test)

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (6) = **9.69**
Prob>chi2 = **0.1383**

Table 14. Results for xttest3 (Test for heteroskedasticity)

Test 3: Test for serial autocorrelation

The final diagnostic was done to test for the presence of autocorrelation. Presence of serial autocorrelation leads to lower standard errors of coefficient that the actual standard errors. It also causes the R-squared value to rise significantly. Its presence was tested using the Wooldridge test for autocorrelation using the Stata command xtserial. The null hypothesis states that there is no serial correlation/ The results in table 15 indicates that there was no autocorrelation in the panel data.

```
Wooldridge test for autocorrelation in panel data
H0: no first order autocorrelation
    F(  1,       5) =      2.193
           Prob > F =      0.1987
```

Table 15. Results for serial autocorrelation test