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DRIVERS OF PLATFORM'S COMPLEMENTS QUALITY: AN EMPIRICAL INVESTIGATION IN THE VIDEO GAME INDUSTRY

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Orientador: Ronaldo Couto Parente

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**"DRIVERS OF PLATFORM'S COMPLEMENTS QUALITY:
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Dissertação apresentado(a) ao Curso de Mestrado em Administração do(a) Escola Brasileira de Administração Pública e de Empresas para obtenção do grau de Mestre(a) em Administração.

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RESUMO

Embora a literatura sobre plataformas sugira que existe um efeito cíclico positivo entre a base instalada da plataforma e a variedade de produtos complementares por causa do princípio de efeitos de redes (ARTHUR, 1989; KATZ e SHAPIRO, 1986), não está claro se esse efeito também ocorre entre a base instalada da plataforma e a qualidade desses produtos complementares. De fato, atributos como a qualidade de produtos complementares são vitais para a criação de valor e adoção de algumas plataformas distribuidoras de conteúdo (SONG et al., 2018; STEINER et al., 2016). No entanto, a investigação de quais fatores impactam a qualidade dos produtos complementares de plataformas é escassa na literatura. A contribuição deste estudo é avaliar empiricamente se há um efeito de causalidade reversa entre a base instalada da plataforma e a qualidade de seus produtos complementares, bem como investigar o impacto do desempenho da arquitetura técnica e da maturidade da plataforma na qualidade dos produtos complementares na indústria de consoles de vídeo game. Os dados coletados contêm informações sobre títulos de jogos exclusivos e de números de vendas de plataformas lançados na sétima geração de consoles de vídeo game no mercado americano, entre novembro de 2005 e novembro de 2013. Os resultados sugerem que a base instalada da plataforma afeta positivamente a qualidade de jogos, mas não há efeito significativo na direção oposta, indicando que não há efeito cíclico entre essas duas variáveis. Além disso, há fortes evidências sugerindo que plataformas com arquitetura técnica mais avançada apresentam maior qualidade de jogos em comparação com suas plataformas rivais. Finalmente, os resultados sugerem que a maturidade da plataforma tem um impacto negativo na qualidade dos jogos. Essas descobertas são importantes para profissionais e pesquisadores da área, lançando uma nova luz sobre o que afeta a qualidade de produtos complementares na indústria de plataformas de vídeo games e elucidando caminho para futuras pesquisas no campo.

Palavras-chave: plataformas, qualidade de produtos complementares, qualidade de jogos, base instalada da plataforma, princípio de efeitos de rede, indústria de vídeo games.

ABSTRACT

Even though the literature of platforms suggests that there is a positive feedback loop effect between platform installed base and complement variety due to the network effects principle (ARTHUR, 1989; KATZ and SHAPIRO, 1986), it is not clear if this effect also happens between platform installed base and complement quality. Indeed, complement attributes, such as complement quality, in some content-delivery platforms are vital for the value creation and adoption of such platforms (SONG et al., 2018; STEINER et al., 2016). However, the investigation of what factors impact the quality of complementary products of platforms is scarce in the literature. The contribution of this study is to empirically assess if there is a reverse causation effect between platform installed base and complement quality as well as to investigate the impact of platform technical architecture performance and platform maturity on complement quality in the context video game consoles industry. Data contains information about exclusive game titles and platforms numbers released in the seventh video game console generation in the U.S. market from November 2005 to November 2013. Results suggest that platform installed base positively affect game quality but there is no significant effect in the opposite direction, indicating that there is no feedback loop effect between those two variables. In addition, there is strong evidence suggesting that platforms with more advanced technical architecture present higher game quality compared to their rival platforms. Finally, results suggest that platform maturity has a negative impact on game quality. These findings are important for practitioners and researchers in the field, shedding new light on what impacts the quality of complements in the video game platform industry and elucidating the path for future research in the field.

Key-words: platforms, complement quality, game quality, platform installed base, network principle effect, video game industry.

CONTENT

1 INTRODUCTION

Many modern products and services are designed to reach consumers through platform technologies. Examples include typically entertainment products based on the interaction between platform and complement architectures (KATZ and SHAPIRO, 1994). For instance, smartphones rely on software applications, e-books readers require digital book content, television sets depend on the availability of TV channels, and video game consoles are useless without compatible game titles (STEINER et al., 2016).

Traditionally, platforms are defined as products, services, or technologies that operate in multisided markets serving as interfaces between different groups of users and facilitating value-creation exchanges (EVANS, 2003; GAWER, 2009; ROCHET and TIROLE, 2006). Consequently, a variety of products such as video games, enterprise software, and online social networks are organized around platforms, which facilitate transactions among firms (or individuals) that (or who) may not have been able to transact otherwise (EISENMANN et al., 2006; GAWER, 2009; HAGIU, 2006).

The premise in the literature of platform-mediated networks is the network effects principle, which states that users place a higher value on platforms with a larger number of other users (CENNAMO and SANTALO, 2013). That is, the value of the platform network is directly proportional to the network size, because the network growth implies a higher probability of meeting users in the other side (SONG et al., 2018). This might be because consumers value direct links with other consumers (i.e. direct network effects) or because they anticipate that platforms with more users, or a larger installed base, will also offer a wider number and variety of complementary products and services (i.e. indirect network effects) (EVANS, 2003; ROCHET and TIROLE, 2003).

Direct network effects arise when additional network members instantly enhance a product's possible uses for an individual, as in the case of direct communication technologies (LEE and O'CONNOR, 2003). For example, in a communication service, the more people using this service, the more numerous their options to interact (STEINER et al., 2016). On the other hand, indirect network effects are specific to system markets, in which a larger installed base of platform users leads to more complementary products, that in turn positively affect customers' perceived value of the platform (STEINER et al., 2016). Thus, it has been suggested that indirect network effects are crucial drivers of platform diffusion and eventual success

(SCHILLING, 1999; SHANKAR and BAYUS, 2003; STEINER et al., 2016). Examples of platforms with strong indirect network effects are content-delivery platforms such as YouTube, Amazon Kindle, and video game consoles, which generate most of their core values from complementary product attributes, not directly from counting the number of users participating in the platform (SONG et al., 2018).

Because of the network effects, platforms are subject to positive feedback loops (KATZ and SHAPIRO, 1986) and increasing returns in supply (ARTHUR, 1989). More network participants increase the market potential for suppliers, who react by enhancing their offers of complements (STEINER et al., 2016). That is, the greater the number of users of a platform, the greater the incentive for third-party developers to introduce more complementary products, and vice-versa (GAWER and CUSUMANO, 2002; GUPTA et al., 1999). In other words, a platform's installed base, or number of active users, influences the choices of developers of complementary goods. Consequently, the stronger the network effects, the greater the installed base influence on the consumer value and, ultimately, on the platform adoption (LEE and O'CONNOR, 2003; STEINER et al., 2016).

Previous research confirms that complement variety has a positive impact on system value and adoption (e.g. CORTS and LEDERMAN, 2009; LANDSMAN and STREMERSCH, 2011). Besides, according to Steiner et al. (2016), most previous work on indirect effects focuses on platform sales and complement quantities analyses (e.g. BASU et al., 2003; CENNAMO and SANTALO, 2013; STREMERSCH et al., 2007). However, even though it is suggested in the literature that a platform installed base influences the variety of its complements resulting in a positive feedback loop, it is not clear if the same effect happens with the quality of complements.

Few studies suggest that installed base is also likely to influence complement quality. According to Steiner et al. (2016), a larger market potential (i.e. installed base) is likely to increase complement production budgets, which would positively impact complement quality. With higher complement quality, the platform value increases from the consumer perspective (BINKEN and STREMERSCH, 2009; GALLAGHER and PARK, 2002), which may influence platform adoption. This is because consumers will choose the platform they believe will provide them with the highest value in the future (BASU et al., 2003, DUBÉ et al., 2010; MARCHAND and HENNIG-THURAU, 2013; STEINER et al., 2016).

Although complement quality is likely to influence platform adoption, to date, few researchers address this phenomenon. Binken and Stremersch (2009) found that, in the context of the U.S. home video game console market, the introduction of a high-quality game increases video game console sales by an average of 14% (167,000 units) over a period of five months. Song et al. (2018) found that exclusive high-quality games increases platform sales performance. Also, in a survey-based study, Steiner et al. (2016) found that hardcore and habitual gamers consider game quality an important factor for platform adoption in a scenario where a new platform is about to be released in the market. For those segments, game quality is more important than game variety on intention to buy a video game console.

However, empirical evidence about what influences complement quality is still scarce in the literature. Besides, as to my knowledge, the positive feedback loop effect that is suggested to happen between platform installed base and complement variety has not been empirically assessed yet between platform installed base and complement quality. Hence, the main question that this study aims to answer is: Does platform installed base influences complement quality and vice-versa in a positive feedback loop way just like suggested in the case of complement variety? In addition, this study investigates which other factors might influence the perception of quality by the eyes of the platform users.

The data collected for this study comprises numbers in the U.S. market of the seventh generation of video game platforms, which is, to date, the latest video game generation with a complete lifespan[1]. The video game console industry provides an appropriate context for this study because it is a representative case of two-sided platform markets on which game titles are developed by independent producers (on the sellers' side) and played by consumers (on the buyers' side) (CENNAMO and SANTALO, 2013). In addition, video game consoles are platforms with strong indirect network effects and ongoing technological progress (CLEMENTS and OHASHI, 2005; CENNAMO, 2018; KRETSCHMER and CLAUSSEN, 2016).

It is known that video game platforms compete in technological generations (ANDERSON et al., 2014), in which each generation represents a group of platforms with comparable hardware specifications (CENNAMO, 2018). Since 1972, there have been eight generations of platforms in the video game industry (CENNAMO et al., 2018). As new

[1] More details about video game generations are found in the following paragraph and in the Literature Review section.

generations emerged in the market, new hardware progress allowed video game platforms to process more content and improved graphics (ANDERSON et al., 2014). This allowed, for example, video game platforms to evolve from processing 2D graphics with limited colors and resolution in the past to process much more detailed high-resolution 3D graphics in the present days. This evolution was possible due to improvements in internal hardware components through the last decades, which may directly impact game quality perception in terms of graphics, resolution, gameplay, and so forth. Thus, this study also investigates the influence of the platform hardware technical architecture on the perception of video game complement quality.

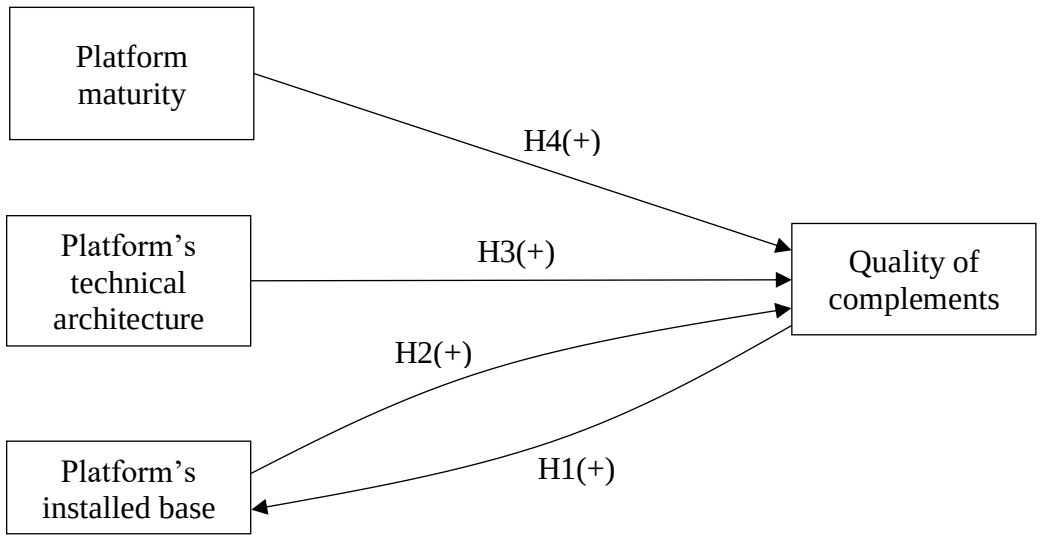
Also, a singular characteristic of content-delivery platforms is that high-quality complements may be costly and time consuming to develop. In the video game industry, for instance, most modern games take about from 1 to 3 years to be developed, even if the length of development depends on various factors, such as the amount of assets, development platform, scale, and genre (SONG et al., 2018). This suggests that modern video game titles are complex and not easy to be developed. Then, it is expected that the time factor is important to game developers to take full potential of the video game hardware technical architecture to deliver the best game performance possible, which may impact the perception of game quality. Hence, this study also investigates the influence of platform maturity on the perception of complements quality.

This study contributes to the extant literature by statistically assessing a reverse causation effect between platform installed base and complement quality and assessing the impact of platform technical architecture performance and platform maturity on complement quality. Figure 1 shows the conceptual model of this study. By investigating what influences complement quality of platforms, this study fills a major gap in the literature, in which empirical evidence is still scarce in the literature. Studies addressing platform complement quality are important not only for researchers in the field due to a lack of studies on this topic, but also for practitioners in the market. Because content-delivery platforms generate most of their core values from complementary product attributes (SONG et al., 2018), and because consumers adopt that platform that will provide them with the highest value in the future (BASU et al., 2003, DUBÉ et al., 2010; MARCHAND and HENNIG-THURAU, 2013; STEINER et al., 2016), the quality of complements is of most importance for platform success as it may directly impact platform sales. The results of this study shed new light on what impacts the quality of complements in the video game platform industry and then may assist practitioners in the

market in their decision-making processes and future strategies planning to gain competitive advantage in the industry.

The remainder of this paper is organized as follows: First, it is done an overview of the extant literature to enlighten important concepts and previous studies. In the following, hypotheses are proposed to assess if platform installed base and complement quality influence each other in a feedback loop way as well as how platform technical architecture performance and platform maturity may influence complement quality. Then, it is shown details about data collection, variables measurements, and method of analysis, which is followed by the analyses results. Finally, it is discussed the implications of the results, an overview of this study's limitations, and future research avenues.

Figure 1 - Conceptual model



2 LITERATURE REVIEW

The literature has been conceptualizing *platforms* as interfaces, often embodied in products, services, or technologies, that can serve to mediate transactions between two or more sides, such as networks of buyers and sellers, or complementors and users (EVANS, 2003; GAWER and CUSUMANO, 2002; HAGIU, 2014; ROCHET and TIROLE, 2003; RYSMAN, 2009). Also, platforms are supposed to facilitate value-creation exchanges between users in different sides (EVANS, 2003; GAWER, 2009; ROCHET and TIROLE, 2006).

Because of that, platforms operate in multisided markets, more commonly in two-sided markets. Broadly speaking, a two-sided market is one in which two sets of agents interact through an intermediary or platform, and the decisions of each set of agents affects the outcomes of the other set of agents. In the case of a video game system, for instance, the platform is the console producer while the two sets of agents are consumers on the one side, and video game developers on the other side (RYSMAN, 2009).

According to the literature, the value of a platform is created according to the premise of the *network effects principle*, which states that users place a higher value on platforms with a larger number of other users (CENNAMO and SANTALO, 2013). More specifically, *direct network effects* arise when the benefit of network participation to a user depends on the number of other network users with whom they can interact (EISENMANN et al., 2006; KATZ and SHAPIRO, 1986). For instance, the value of online social networks such as Facebook and LinkedIn increases with the number of participants on the site (MCINTYRE and SRINIVASAN, 2017). In other words, direct network effects arise when the users in the same side of a platform are allowed to interact with each other, and these effects get stronger as the number of users increase.

Besides, a platform value can also be augmented by *indirect network effects*, whereby different sides of a network can mutually benefit from the size and characteristics of the other side (BOUDREAU and JEPPESEN, 2015; EVANS, 2003; HAGIU, 2014; ROCHET and TIROLE, 2003). For example, users of video streaming services such as Netflix value a large number of available movies and programs, while movie studios and other content providers benefit from a large base of viewers (MCINTYRE and SRINIVASAN, 2017).

Examples of platforms that present strong indirect network effects are content-delivery

platforms such as Netflix and Amazon Kindle, as well as video game systems. An important characteristic of such platforms is that their core values can be augmented by the availability and attributes of *complementary products* (or *complements*), and not just by counting the number of users in these platforms (SONG et al., 2018).

Traditionally, in the Strategy field, complementary assets, as discussed by Teece (1986), are required to the successful commercialization of an innovation. In other words, the successful commercialization of an innovation requires the conjunction utilization of other capabilities or assets. For example, services as marketing, competitive manufacturing, and after-sales support are almost always needed for this purpose (TEECE, 1986).

Similarly, complements are vital for the success of platforms. Specifically, in this context, complements describe goods and services built on a platform that enhance the value of a core good to a network via indirect network effects, in which the value of the platform would be greater in conjunction with the complement than without it. (GAWER, 2009; YOFFE AND KWAK, 2006; ZHU and IANSITI, 2012). The interaction between platforms and their complements is paramount for the proper provision of the proposed service or product. For instance, smartphones rely on software applications, e-books readers require digital book content, television sets depend on the availability of TV channels, and video game consoles are useless without compatible game titles (STEINER et al., 2016).

In this context, *complementors* are the independent providers of complementary products to mutual customers (BOUDREAU and JEPPESEN, 2015; YOFFE and KWAK, 2006). In the video game industry, the complementors are the game developers, which play an important role in the commercialization of video game platforms because they are the agents that create the main complements for those platforms: the game titles.

For modern video games consoles, there are other complements such as DVD or Blu-Ray function, and access to video streaming services, such as YouTube and Netflix. Nevertheless, similarly to Song et al. (2018), this study assumes that consumers buy a video game console for playing games since DVD or Blu-ray players' average price is a tenth of the game consoles.

According to Zhu and Iansiti (2012), video game consoles are proprietary systems in which a single firm owns the hardware technology and competing platforms are incompatible with it. In addition, video game consoles compete in technological generations (ANDERSON

et al., 2014; CENNAMO, 2018). Each generation represents a group of consoles with comparable hardware specifications (CENNAMO, 2018). There have been eight generations of platforms in the video game industry from 1972 to date (CENNAMO et al., 2018), in which each generation lifespan is approximately 6 years (SONG et al., 2018).

Across the video game generations, new hardware progress allowed more content and improved graphics, which also increased the costs of game development (ANDERSON et al., 2014). For instance, in 1995, a high-quality game title (often called a AAA game) had a $1.5 million budget, while in 1999 it had around $3 million to $4 million budget, and in 2010 it cost on average $60 million to develop (CENNAMO et al., 2018).

The development time of games has also increased. The average development time required for fifth-generation consoles was 6 to 9 months, while in the seventh generation this has risen to 19 months (CENNAMO et al., 2018). Also, according to Song et al. (2018), most modern games take from 1 to 3 years to be developed, even if the length of development depends on various factors, such as the amount of assets, development platform, scale, and genre.

The seventh generation of video game consoles, in which this study bases the empirical analyses, were composed of three platforms: the Microsoft's Xbox 360, the Sony's PlayStation 3, and the Nintendo's Wii. The first mover in that generation was the Xbox 360, which was released in the U.S. market in November 2005. The competitor platforms, PlayStation 3 and Wii, were released one year after, in November 2006.

Each of those platforms has already its successor, as each of the platform producers has already released in the market the eighth generation consoles. In the U.S. market, Nintendo released the Wii U in November 2012, while Microsoft and Sony released, respectively, the Xbox One and the PlayStation 4 in November 2013. Consequently, to date, the seventh generation of video game consoles is the latest with a full lifespan. That is, all the platforms were released, commercialized, and were eventually substituted by newer generation consoles by their producers, providing a suitable context for the empirical analyses of this study.

Video game consoles are platforms that present strong indirect network effects (SONG et al., 2018). It has been suggested that platforms with strong indirect network effects are subject to positive feedback loops (KATZ and SHAPIRO, 1986) and increasing returns in supply (ARTHUR, 1989), as more network participants in the platform increase the market potential

for suppliers, who react by enhancing their offers of complements (STEINER et al., 2016). That is, the greater the number of users of a platform, the greater the incentive for third-party developers to introduce more complementary products, and vice-versa (GAWER and CUSUMANO, 2002; GUPTA et al., 1999).

Even though this positive feedback loop between complement variety and platform users (i.e. installed base) is suggested in the literature, there are no studies, as to my knowledge, to assess if this also happens between complement quality and platform installed base. In fact, according to Steiner et al. (2016), most previous work on indirect effects focuses on platform sales and complement quantities analyses.

For example, Venkatraman and Lee (2004) showed that supporting a platform with a large user base is more valuable to game developers as it offers a greater potential market for their games relative to platforms with smaller subsets of users, suggesting that game developers want to build their games on the most popular platforms. In other words, neither consumers nor game developers will be interested in the video game console if the other party is not (RYSMAN, 2009).

Clements and Ohashi (2005) examined the extent of indirect network effects in the U.S. video game industry. Their results confirm the importance of a platform's complements variety, along with penetration pricing, for a platform's success. Also, Stremersch et al. (2007) examined the pattern of indirect network effects between hardware sales and complement availability across nine two-sided markets, including black-and-white television, CD, CD-ROM, color television, DVD, Game Boy, i-mode, Internet (World Wide Web), and laser disc. Their results suggest that, in most of these markets, hardware sales influence complement availability.

Corts and Lederman (2009) studied the relationship between video game platforms demand and complement availability in the U.S. market. Their analysis was based on monthly data on U.S. platforms sales and complement availability for major home video games systems from 1995 to 2005. Results suggested that the demand for a particular video game console increases with the availability of complements for that console. In addition, they found that the supply of complements for a console depends positively on the installed base on that console.

In the context of video game platform market, Landsman and Stremersch (2011) investigated the influence of multihoming (i.e. the decision of a complementor to produce the

same video game title to more than one platform) on video game console sales. Their results suggest that increased platform-level multihoming of game titles hurts platform sales, but this effect vanishes as platforms matures. In addition, they found that platform-level multihoming of game titles affects platform sales more strongly than game title variety.

Cennamo and Santalo (2013) empirically analyzed the dominant strategies adopted by platform producers in the U.S. video game industry to assess their impact on platform sales performance. They found that when platforms producers pursue, at the same time and with equal intensity, to stimulate the variety of game titles and securing a large fraction of their game library with title exclusivity, it diminishes the benefits of each strategy in a way that it hurts platform sales performance.

To date, only few studies have addressed platform complement quality. Binken and Stremersch (2009) found that, in the context of the U.S. home video game console market, the introduction of a high-quality game increases video game console sales by an average of 14% (167,000 units) over a period of five months. Also, in a survey-based study, Steiner et al. (2016) found that the video game console market is strongly fragmented and that the perceptions of network effects differ between the various target segments. According to the authors, the segments of hardcore and habitual gamers consider game quality over game variety when deciding to adopt a platform in a scenario where a new video game console is about to be released in the market.

Through an empirical approach, Song et al. (2018) found that exclusive high-quality games increase platform sales performance. In addition, Cennamo et al. (2018) investigated the perception of quality among non-exclusive video game titles and found that titles that are released in more than one platform present lower quality perception on a technologically more complex console than on a less complex one. However, it is not clear if the same effect happens with exclusive game titles.

Even though quality of complements of platforms is an under-researched topic in the literature, it is of great interest for practitioners in the market. Williams (2002) states that the quality of games is so important in the video game industry that entrants rely on large-scale successes. This study aims to contribute to the literature by providing empirical evidence in what influences complement quality, that is still scarce in the extant literature, and assessing if the suggested positive feedback loop between platform installed base and complement variety

also happens between installed base and complement quality, which to date, as to my knowledge, has not been tested yet. More specifically, because video game platforms have exhibited enormous technical progress in the last decades and because game development is costly and time consuming, this study, besides assessing a reverse causation between platform installed base and complement quality, also investigates the influence of platform technical architecture and platform maturity on complement quality.

3 THEORY DEVELOPMENT

According to some authors, platform producers need to reach a critical mass of console adopters (i.e. the installed base) to stimulate complement production and foster further platform adoption in order to gain a competitive advantage over their rivals (ANDREOZZI, 2004; STEINER et al., 2016). Stimulating game console adoption and, subsequently, game production is of the utmost importance, because video game consoles are pure network goods. In other words, the hardware itself has no stand-alone value without the complementing games and vice versa (STEINER et al., 2016).

From a company perspective, the current and expected installed bases are relevant when deciding on a platform's complement supply (BASU et al., 2003). Complement developers might offer complementary products even if the current installed base does not justify their supply because they are expecting the installed base to grow as new complements are developed for the platform. In other words, the present complement variety is the result of a platform's current and expected market potential (STEINER et al., 2016).

This is common to happen in the video game platform industry. Because video game platforms are useless without compatible game titles, new video game consoles are released in the market in conjunction with some game titles developed for that platform. Other titles are released few weeks or months later, and it continues throughout all the platform life, constantly increasing game variety while the platform matures. Since most of the modern games take from 1 to 3 years to be developed (SONG et al., 2018), it is likely that the games released in the beginning of the platform lifespan began to be developed even before the video game console was released in the market.

Because some game developers decide to produce game titles to platforms that has not been released yet, the development costs of these games are not justified by the platforms installed bases, as they have not generated any sale. However, these costs are expected to be amortized since the platforms are released and amass adopters. As platform producers aim to rapidly seek adopters, they rely on large-scale successes right on the beginning of the platform life (WILLIAMS, 2002), and the development and release of game titles continue as video game platforms mature. With higher complement quality, the platform value increases from the consumer perspective (BINKEN and STREMERSCH, 2009; GALLAGHER and PARK, 2002), which may positively influence platform adoption.

In fact, according to Binken and Stremersch (2009), the introduction of a high-quality game increases video game console sales by an average of 14% (167,000 units) over a period of five months. In addition, Steiner et al. (2016) found that hardcore and habitual gamers take game quality as one of the most important factors when considering adopting a video game platform. Hence, with the release of high-quality game titles, it is expected that the quality of games influences the number of platform adopters in a positive way.

Hypothesis 1 (H1): Game quality is positively associated to the platform installed base.

Previous studies suggest that complementor decisions are based on the platform installed base. According to Corts and Lederman (2009) study, the supply of complements for a console depends positively on the installed base on that console. That is, game developers prefer to build their games on the most popular platforms because supporting a platform with a large installed base offers a greater potential market for their games relative to platforms with smaller subsets of users (VENKATRAMAN and LEE, 2004).

Across the video game generations, the development costs of game titles have increased considerably. For instance, in 1999, the development costs of a single AAA game had around $3 million to $4 million budget, while in 2010, it costed in average $60 million to be developed (CENNAMO et al., 2018). Hence, the preference for supporting most popular platforms is very important for game developers due to the high costs of developing games in that industry. The bigger the installed base the platform presents, the more the complement development costs are expected to be amortized. Besides, according to Steiner et al. (2016), a larger market potential (i.e. installed base) is likely to increase complement production budgets, which would positively impact complement quality. Thus, bigger installed bases are expected to influence game quality because, the bigger the potential market, the more game developers are supposed to be stimulated to invest in game development.

However, a platform installed base can justify the decision of complementors to develop games to that platform only after it is released in the market and generated a considerable amount of sales (i.e. has amassed a considerable installed base). Furthermore, because the decisions about starting the development of game titles in a certain platform are justified according to its current installed base, game developers have to take into account the platform installed base at the moment that these decisions were made. According to Cennamo et al. (2018), the average development time of a game title in the seventh video game generation was

of 19 months. Therefore, once a platform has reached a considerable installed base amount, the decision to start developing a new game title in the seventh generation was probably justified on the platform installed base as of, in average, 19 months before the game was released in the market. Hence, it is expected that the platform installed base as of the beginning of the game title development is positively associated to the game quality.

Hypothesis 2 (H2): Installed base as of the beginning of the game titles development is positively associated to game quality.

Hypotheses 1 and 2 are proposed to assess the opposite directions of influence between platform installed base and game quality. That is, in conjunction, both hypotheses evaluate if there is a positive feedback loop effect between platform installed base and game quality. Because there is a gap of studies addressing this topic in the literature to date, it is still unclear how game quality is affected by other factors. Furthermore, as discussed earlier, video game platforms hardware improved every time a new generation emerged in the market. Also, modern game titles are supposed to be costly and time consuming to be developed. Then, platform technical architecture and platform maturity are expected to impact game quality. The following hypotheses investigate how platform technical architecture and platform maturity are associated to game quality.

In the last decades, video game consoles have exhibited enormous technical progress. The technical architecture of platforms, that is, the technological capabilities of a platform, and the way platform technological components function and connect to platform complements (BALDWIN and WOODARD, 2009; TIWANA 2015; YOO et al. 2010) have improved through the video game generations, allowing game developers to innovate with their products and making more attractive games. For instance, progress in processing speed by consoles and associated programming techniques by developers explains the improvements in graphic quality and play experience in video games (RYSMAN, 2009).

Because each video game platform presents a unique technical architecture, complements frequently must be personalized to a platform's core technological functions and interface specifications to take full advantage of its performance (ANDERSON et al. 2014; CENNAMO et al., 2018; CLAUSSEN et al. 2014; TIWANA 2015). Hence, it is expected that video game platforms present different game performance due to their distinct technical architectures. This may directly impact the quality of games because, a priori, platforms with

more advanced technological architectures than its rivals would allow game developers to build game titles with better graphics, higher resolution, higher frame rates, and so forth.

In fact, to attract both users and game developers, platform producers aim for high hardware power to push cutting-edge graphics games when releasing new consoles (KRETSCHMER and CLAUSSEN, 2016; ZHU and IANSITI, 2012). According to Anderson et al. (2014), there are three main components of platform architecture that affect hardware performance: Central Process Unit (CPU, including coprocessors), Graphics Processing Unit (GPU, including coprocessors), and Random Access Memory (RAM). Therefore, it is expected that the platforms that present more advanced technical specifications on these three components when compared to their rivals will also present better game quality because more advanced technical architecture allows the development of games with better graphics, higher resolution, higher frame rates, and so forth. Table 1 shows the technical specifications on these three components on each console of the seventh generation.

Hypothesis 3 (H3): Compared to the rivals, platforms with more advanced hardware technical architecture performance will present higher game quality.

Table 1 - Technical architecture and lifetime by platform

Console	Console lifespan [a]	Platform producer	CPU [b] (MHz)	GPU [b] (MHz)	Total RAM (Mb)
Xbox 360	Nov. 2005 to Nov. 2013	Microsoft	3200	500	512
PlayStation 3	Nov. 2006 to Nov. 2013	Sony	3200	550	512
Wii	Nov. 2006 to Nov. 2012	Nintendo	729	243	88

[a] From release date to next generation console release date
[b] Maximum processing speed in megahertz

Considering the maximum processing speed of the CPU and GPU, and the total amount of RAM shown in Table 1, the video game platform of the seventh generation that presents the technical architecture with the highest processing power is the PlayStation 3, followed by the Xbox 360 and the Wii. Then, if more advanced technical architecture is positively associated to game quality, it is expected that the exclusive games released for the PlayStation 3 present higher average game quality than the Xbox 360, which in turn, would present higher average game quality than the Wii.

Even though the hardware of video games has technically progressed in the last years, it still imposes limitations to game performance and game development. Ethiraj (2007) argues

that the performance of personal computers is influenced by the constraints of internal hardware components. These components pose as bottlenecks to the system performance, even if there are slacks components (those that do not pose a bottleneck to the system performance).

This also applies to video game platforms hardware. That is, the performance of games developed for a certain platform is bounded to what the platform hardware can deliver. Specifically speaking, this implies that a game developer will build games that present graphics, resolution, frame rate, quantity of colors, and so forth, that will be limited to what the platform hardware can process, depending on the bottlenecks of its hardware components.

When a video game console with a new technical architecture is released in the market, game developers may face difficulty in building games for it. Because the platform is only available in the market for a short time, complementors might not have the enough knowledge about its technical architecture to exploit its full potential, which would harm the quality of games released in the platform early stage.

However, as the platform matures, game developers have more time to know better the platform technical architecture. As the platform gets "older", the learning curve of game developers increases as they have more familiarity with bottleneck components. This would allow them to get closer in exploiting the full potential of the platform hardware, and consequently, getting the best game performance possible. Thus, platform maturity is expected to positively impact the quality of games because exploiting the full potential of the platform technical architecture would allow the development of games with better graphics, frame rates, and so forth, than the games released in the beginning of the platform life.

Hypothesis 4 (H4): Platform maturity is positively associated to game quality.

4 METHODOLOGY

4.1 DATA COLLECTION

For the empirical analyses, it was collected data of game titles for each video game platform from *metacritic.com*. This website aggregates reviews of entertainment products such as albums, games, movies, and books. The site collects various sources of game reviews of other video game specialized websites and, based on averages of these reviews, assigns game titles a value from zero to one hundred (the metacritic score). The website also provides other game information, such as available platform(s), release date, publisher, and developer.

These game titles reviews are usually based on opinions given by professional reviewers, who are assigned to play the game and to write about their impressions about what is good and bad in the game. Most of these reviews assign a numeric score based on, for example, the game's graphics, gameplay, and plot. Therefore, the higher the score given to the game by the reviewer, the better the game is and consequently, the higher its quality.

Some authors claim that exclusive complements are essential for platforms competitive advantage. Song et al. (2018) argue that exclusive content is a strong differentiating factor for platforms in their quest for new adopters, in which platforms prefer high-quality complements to be exclusive rather than being also available on other platforms. Indeed, according to Binken and Stremersch (2009), high-quality exclusive games are responsible to affect the competitive positions of each platform, making video game consoles to be sold. Thus, the analyses of this study comprise the metacritic scores of only generation exclusive video game titles, which are those titles that were released for only one video game platform belonging to a specific generation, which, in this study, is the seventh generation.

In addition, for each video game platform, it was collected data about each console sales numbers from *vgchartz.com*, an industry research firm which publishes weekly estimates of video game platform sales. Other scholars have recently used this source (e.g. CUNNINGHAM et al., 2016; SONG et al., 2018). Also, for each platform, it was collected data about the specifications of the three main components that influence game performance according to Anderson et al. (2014): CPU, GPU, and RAM. Data about this was collected from *wikipedia.com* and is summarized in Table 1. Furthermore, it was also collected data about the prices of all platforms in the seventh generation of video games along each console maturity

time.

To investigate the effects between the variables in the proposed hypotheses in a generation in which all platforms have a complete lifespan, it was collected data of the seventh generation consoles from when each platform was released in the market until the introduction of the eighth generation console by each platform producer. That is, data for the PlayStation 3 ranges from November 2006 to November 2013 (when Sony released the PlayStation 4); data for the Wii ranges from November 2006 to November 2012 (when Nintendo released the Wii U); and data for the Xbox 360 ranges from November 2005 to November 2013 (when Microsoft released the Xbox One). Based on these criteria, the final sample consists of 1,655 exclusive game titles released for these video game platforms in the afore mentioned timespan in which metacritic scores were available.

4.2 VARIABLE MEASUREMENTS

In the following, it is provided details about how each variable in the hypotheses proposed in this study was operationalized. Also, it is discussed the concern to control for variables such as platform price and platform fixed effects, as well as how these variables were operationalized.

In this study, game quality was operationalized by each game title metacritic score, that ranges from zero to one hundred, in which the higher, the better. Because each specialized website provides the critic review only once for a game title when it is released in the market (or at least after a short time of its release), game quality is a time invariant variable in this study. Even if a game title receives correction updates after some time of its release, it is not common for new critic reviews to be made on that game.

Platform installed base was operationalized by the cumulative sum of video game console sales numbers in a weekly basis. Video game consoles are sold along all their lifetime. Because of that, a platform installed base always tend to grow while time passes, which makes this variable time variant.

Platform maturity, which is also a time variant variable which in this study consists in the platform life time in weeks, ranging from when the platform was released in the market (week 1) to the release of the next generation console of the same platform producer.

Platform technical architecture was operationalized according to the specifications of the three main components that influence the video game console performance: CPU, GPU, and RAM. More specifically, for CPU and GPU, it was considered the maximum processing speed of each of these components in megahertz (MHz), while for the RAM, it was considered its total amount in megabytes (Mb). In the seventh generation, the specifications of these three components among the video game platforms did not change along their life cycle. Hence, the platforms that present better combinations of these three components (i.e. higher processing speed for CPU and GPU, and higher amount of RAM), present better technical architecture compared to their rivals.

To assess the hypotheses, it is important to control for some variables that might also influence the dependent variables in this study analyses. Previous research suggests that platform hardware price have a major influence on platform adoption (e.g. CHINTAGUNTA et al., 2009). In addition, price is an important driver of platform penetration capacity, especially in multisided markets (HAGIU, 2006; ROCHET and TIROLE, 2003). By lowering the access price, a platform can increase its installed base and offer a more attractive market to producers of the platform's complementary goods, which may also influence complement quality. In the last generations, as platform matures, it was common to platform producers to introduce new versions of video game consoles with similar technical specifications, which may lead to different models of the same platform (but with the same specifications about CPU, GPU, and RAM) being sold with different prices in the market. Thus, platform price may vary in time. Platform price is defined here as the price of the cheapest model of each video game console across the maturity time.

Another factor that should be important to control for is the first entrance in the market. In the seventh generation, the Xbox 360 was released in the market one year before than the PlayStation 3 and the Wii. This could have given some competitive advantage to the Xbox 360 over its rival platforms in the generation. Zhu and Iansiti (2012) claim that first entrants may experience a "monopoly equilibria" in which all consumers and complement developers adopt one platform because they believe that everyone else will adopt the same platform. That is, because late entrants lack installed bases, consumers tend to hold favorable expectations of established platforms. This could lead to a "winner-take-all" outcome to the first entrant, in which the platform with the largest number of users would "tip the market" in its favor in (CENNAMO and SANTALO, 2013), which may impact platform installed base and game quality. To control for this and for other unobservable factors that do not change in time between

the different platforms, it was included platform fixed effects in the analyses by creating dummy variables for two of the three platforms in which they take value 1 for games released to one focal platform and value 0 if otherwise.

4.3 MODEL ESTIMATION

Because we want to assess the influence of game quality on platform installed base and vice-versa, as well as the influence of platform maturity on game quality, while controlling for other variables, Hypotheses 1, 2, and 4 were tested by Ordinary Least Squares (OLS) regressions in which standard errors were clustered at the platforms level. With respect to Hypothesis 3, as we are interested in compare, in average, the quality of games released across the video game platforms, and because the technical specifications of CPU, GPU, and RAM of each platform do not change in time, its assessment was conducted through t-tests analyses.

To assess if there is a feedback loop effect between platform installed base and game quality, which might suggest a reverse causation, it is important to consider temporality between these two variables. According to Hill (1964), temporality is one the conditions to be met so a causation between two associated variables is most likely to occur. That is, the cause always must occur before the effect.

Then, to test Hypothesis 1, which predicts that the quality of games influences the platform installed base, it is important to guarantee that the release and the review of the game titles happen before the sales of the platforms in which these games were developed for. Thus, to test Hypothesis 1, the quality of game titles released in a certain week for a certain platform is the explaining variable of the platform installed base of one week ahead. Here, because platform price may impact platform sales, as discussed before, it was considered important to control for platform price at the time of the game titles releases. That is, when a potential platform adopter is attracted by an exclusive game title release, he or she may also consider the platform price when deciding to adopt, or not, that platform to play that exclusive game.

Equation 1 shows the regression equation to test Hypothesis 1, where $Game\ Quality\ _{i,j}^{t}$ is the metascore of the game title *i* released for the platform *j* in week *t*; $Installed\ base\ _{j}^{t+1}$ is the installed base of the platform *j* 1 week ahead of the release of the game title *i*; α_j represents platform fixed effects; $Price\ _{j}^{t}$ represents the price of the cheapest model of platform *j* at week *t;* and ε is the error term.

$$Installed\ base\ _j^{t+1} = \alpha\ _j + Game\ Quality\ _{i,j}^{t} + Price\ _j^{t} + \varepsilon \quad (1)$$

Similarly, to test Hypothesis 2, which predicts that the platform installed base influences the quality of games, it is important to guarantee that the platform sales numbers to come before the release of game titles. Because the game titles in the seventh generation took in average 19 months (or 82 weeks) to be developed, to test Hypothesis 2, it was regressed the quality of games released in a certain week for a certain platform on the platform installed base as of 82 weeks before the release date of the game title. Here, it was controlled for platform price also at the time of the beginning of game title development because, as game developing is time consuming, game developers might not be sure how much the platform models prices will be at the time of the game title release. The decision to cut prices or to introduce cheaper console models in the market is of the platform producers. Hence, similarly to platform installed base, in this hypothesis, it was controlled for platform price as of 19 months (or 82 weeks) before game title release.

Equation 2 shows the regression equation to test Hypothesis 2, where $Game\ Quality\ _{i,j}^{t}$ is the metascore of the game title *i* released for the platform *j* in week *t*; $\alpha\ _j$ represents platform fixed effects; $Installed\ base\ _j^{t-82}$ is the installed base of the platform *j* 82 weeks before of the release of the game title *i*; $Price\ _j^{t-82}$ represents the price of the cheapest model of platform *j* 82 weeks before of the release of the game title *i*; and ε is the error term.

$$Game\ quality\ _{i,j}^{t} = \alpha\ _j + Installed\ base\ _j^{t-82} + Price\ _j^{t-82} + \varepsilon \quad (2)$$

To assess Hypothesis 3 by t-test, it was considered all exclusive games released for each video game platform along all their timespan included in the sample. That is, for the Xbox 360, it was computed the average quality of all exclusive games released for it from November 2005 to November 2013. For the PlayStation 3, it was computed the average quality of all exclusive games released for it from November 2006 to November 2013. For the Wii, it was computed the average quality of all exclusive games released for it from November 2006 to November 2012. Then, it was considered all possible platform pairwise comparisons to assess if the exclusive game quality averages of each platform were significantly different from each other.

It was observed that the variances of the metascores of the exclusive game titles released for the video game platforms in the considered timespan were not similar (i.e. they do not present homoskedasticity), which harms one of the main t-test assumptions. To correct for this

in the assessment of Hypothesis 3, it was applied the Welch's t-test, that is more suitable when the different groups (here the different platforms) present unequal variances in the variable of interest, at the same time that it keeps the t-test essence and makes results more accurate (WELCH, 1947). In addition, the degrees of freedom for the Welch test was determined with the Welch-Satterthwaite equation (SATTERTHWAITE, 1946).

To test Hypothesis 4, which predicts that platform maturity is positively associated to game quality, it was regressed the metascores of the game titles on the platform maturity time. Here, it was considered important to control not only for platform price and platform fixed effects, but also for platform installed base because, just like platform maturity time, platform installed base also increases with time. Also, in this hypothesis, we are not interested in assuring a cause and effect relationship between the assessed variables just like in Hypotheses 1 and 2. Here, we are interested in finding association between variables. Thus, the temporality condition as discussed by Hill (1964) was not strictly applied in the assessment of this hypothesis. Hence, all variables were considered in the same time space, which is the time of game title release.

Equation 3 shows the regression equation to test Hypothesis 4, where $Game\ Quality\ {}^{t}_{i,j}$ is the metascore of the game title *i* released for the platform *j* in week *t*; $\alpha_{\ j}$ represents platform fixed effects; $Maturity\ time\ {}^{t}_{j}$ is the maturity time in weeks of platform j in week *t*; $Installed\ base\ {}^{t}_{j}$ and $Price\ {}^{t}_{j}$ represent respectively, the installed base of the platform *j* in week *t*, and the price of the cheapest model of platform *j* at week *t*; and ε is the error term.

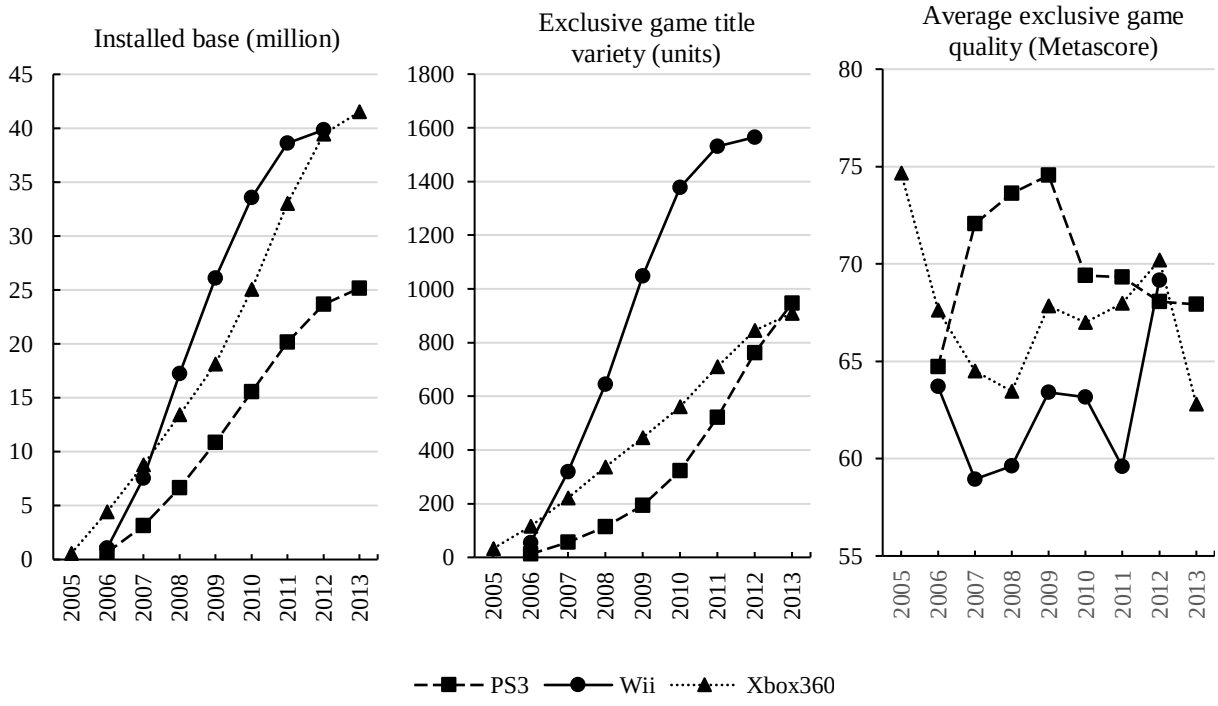
$$Game\ quality\ {}^{t}_{i,j} = \alpha_{\ j} + Maturity\ time\ {}^{t}_{j} + Installed\ base\ {}^{t}_{j} + Price\ {}^{t}_{j} + \varepsilon \qquad (3)$$

5 RESULTS

5.1 DESCRIPTIVE STATISTICS

As shown in Figure 2, in the first three years of the seventh generation, the Xbox 360 amassed the highest number of users in the U.S. market. Being the first entrant in the generation helped the platform to take the lead in the U.S. market in that period. Nevertheless, from 2008, the Wii took the lead of the U.S. market by surpassing the number of users of the Xbox 360, and kept that position until the release of the Wii U in the late 2012. In addition, the PlayStation 3, in the U.S. market, was the platform that amassed the smaller quantity of installed base along all the generation when compared to its rivals.

Figure 2 - Installed base, game variety, and average game quality by platform over the years



When comparing the variety of exclusive game titles in each platform over the years in Figure 2, it can be seen that the Xbox 360 was the leading platform in game variety until 2006, one year after it was released in the market. After that, the Wii offered the highest exclusive game variety until the end of the generation. For almost all the generation time, the PlayStation 3 was the platform that offered the smallest game title variety, only catching up with the Xbox 360 in the last couple years in the generation.

When comparing the average exclusive game quality of each platform over the years, it can be seen that the Xbox 360 presented the highest average game quality for the exclusive titles released until 2006. Afterwards, the PlayStation 3 presented the highest average game quality for the exclusive games released in the five consecutive years, from 2007 to 2011. For almost all the generation time, the Wii presented the smallest average exclusive game quality, only presenting similar average when compared to its rivals for the exclusive games released in 2012, just before the introduction of its successor, the Wii U.

Also, Figure 2 suggests a strong positive time trend of the installed base and exclusive game title variety of all platforms, while this time trend is not clear on game quality. This was already expected. Because platform installed base is defined in this study as the cumulative sum of platform sales numbers, every time a video game console is sold, the platform installed base grows. That is, each console sale represents, at least, one more potential buyer for the games developed for that platform. Game variety also tends to grow in time because new game titles are constantly released in the market. That is, each new game title released in the market increases the catalogue of games available to the platform it was developed for. There is no "expiration date" to a game title, in a way that the games released in the beginning a platform life keep being available in the future for consumers to buy.

Game quality, however, in the way it was operationalized in this study, is bounded from zero to 100, which is the range of the metascore. Furthermore, review scores do not have a cumulative property. In other words, the review score of a game title released in a specific point in time do not (necessarily) impact the review scores of other games released in the future, which explains why the average exclusive game quality graph is different from the others presented in Figure 2.

Summary statistics and pairwise correlations are shown in Table 2. There is a strong correlation between platform installed base and platform maturity (0.848), which shows the importance to control for installed base in Hypothesis 4. This was expected as both variables increase in time. In addition, it was tested the variance inflation factors (VIFs) in all regression analyses in this study, in which none of them were higher than the cutoff value of 10, showing that the results are not driven by multicollinearity.

Table 2 - Descriptive statistics and correlation matrix

	Mean	S.D.	Min	Max	1	2	3
1. Game quality	65.653	15.005	11	97			
2. Installed base (million)	16.534	10.443	0.139	41.527	-0.021		
3. Platform maturity	166.629	99.242	1	417	0.065**	0.848***	
4. Platform price	292.1	67.126	199	499	0.172***	-0.583***	-0.290***

Note: N = 1,655. * p < 0.05; ** p < 0.01; *** p < 0.001

5.2 MAIN RESULTS

The regression results of Hypotheses 1, 2, and 4 are given in Table 3. The first column of each hypothesis results contains only control variables. All models provide clustered standard errors at the platforms level and platform fixed effects. Hypothesis 1 predicted that game quality is positively associated to platform installed base. Even though the coefficient of game quality is positive, it is not significant (β = 23,105.150; p > 0.1), suggesting that game quality does not have a significant effect on platform installed base. Also, the coefficient of the control variable of platform price is negative and significant at 0.1 level of significance (β = -163,072.723; p < 0.1), suggesting that platform price have a moderate negative effect on platform installed base, indicating that platforms with higher prices might sell less. All in all, Hypothesis 1 was not supported.

Hypothesis 2 predicted that platform installed base as of the beginning of the game titles development (i.e. 19 months or 82 weeks before game titles release) is positively associated to game quality. The installed base coefficient is positive and significant ($\beta = 0.128\times10^{-6}$; p < 0.01), suggesting that platform installed base as of 82 weeks before game release has a strong and positive effect on game quality. Thus, Hypothesis 2 was supported.

Hypothesis 3 predicted that, compared to the rivals, platforms with more advanced hardware technical architecture would present higher game quality. The Welch-Satterthwaite's t-test results showed that, on average, exclusive games released for the PlayStation 3 presented significantly higher game quality (M = 70.114; SE = 0.676) than the exclusive games released for the Xbox 360 (M = 66.957; SE = 0.567; t(859.92) = 3.578; p < 0.001). Exclusive games released for the PlayStation 3 also presented significantly higher game quality (M = 70.114; SE = 0.676) than the exclusive games released for the Wii (M = 61.635; SE = 0.624; t(917.89) = 9.219; p < 0.001). In addition, exclusive games released for the Wii presented significantly

smaller game quality (M = 61.635; SE = 0.624) than the exclusive games released for the Xbox 360 (M = 66.957; SE = 0.567; t(1,254.97) = -6.316; p < 0.001). Then, the platforms that present higher game quality are, in decreasing order, PlayStation 3, Xbox 360, and Wii. Thus, based on the specifications of CPU, GPU, and RAM, Hypothesis 3 was supported. Figure 3 shows the average exclusive game quality for each console.

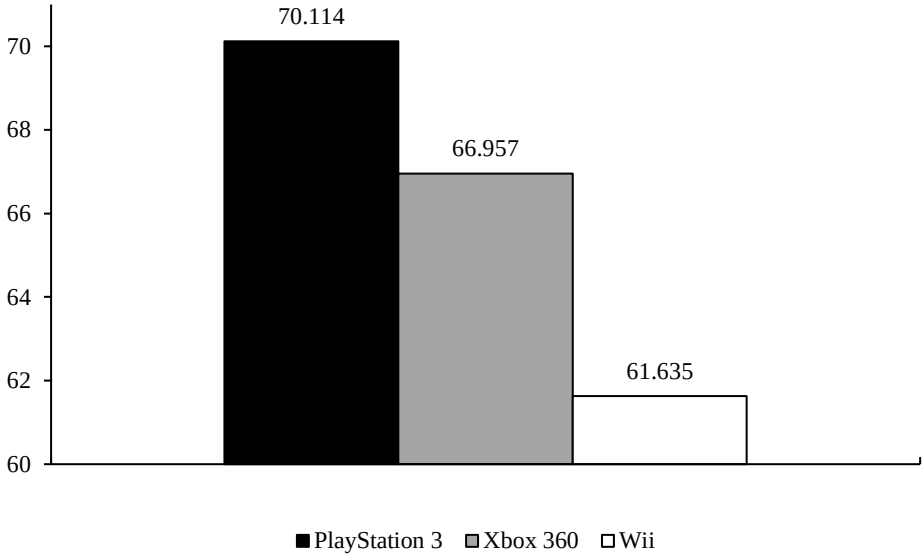
Table 3 - Results from OLS regression estimation

	H1		H2		H4	
Dependent variable	Installed base (million) (1 week ahead)		Game quality		Game quality	
	(1)	(2)	(1)	(2)	(1)	(2)
Independent variables						
Game quality		0.023				
		(0.011)				
Installed base in million (82 weeks before)				0.128**		
				(0.010)		
Platform maturity						-0.058*
						(0.013)
Control variables						
Platform price	-0.163+	-0.163+			0.023*	-0.007
	(0.542)	(0.541)			(0.004)	(0.004)
Platform price (82 weeks before)			0.004	0.016		
			(0.023)	(0.019)		
Installed base in million					0.097	0.506+
					(0.047)	(0.132)
Constant	68.178+	66.619+	68.670*	62.765*	61.005***	77.232***
	(18.002)	(17.260)	(8.526)	(7.168)	(1.748)	(2.025)
Platform fixed effects	YES	YES	YES	YES	YES	YES
N	1,651	1,651	1,289	1,289	1,655	1,655
R-squared	0.527	0.528	0.042	0.044	0.054	0.059

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Hypothesis 4 predicted that platform maturity is positively associated to game quality. The platform maturity coefficient is significant though negative (β = -0.058; $p < 0.05$), suggesting that platform maturity has a negative effect on game quality. Thus, Hypothesis 4 was not supported on the expected valence.

Figure 3 – Average exclusive game quality in metascore by console



6 DISCUSSION AND CONCLUSION

This study empirically assesses if platform installed base and platform complement quality affect each other in a positive feedback loop way, as well as the effect of platform technical architecture and platform maturity on platform complement quality. The sample contains numbers about generation exclusive game titles released to the seventh generation video game platforms from 2005 to 2013. Results suggest that there is a significant positive influence from the platform installed base to game quality only in this direction, indicating that there is no feedback loop effect between those two variables.

This result suggest, on the one hand, that complementors invest more in game development, positively impacting game quality, when there is a bigger potential market (i.e. platform installed base) for their games, confirming what was proposed by Steiner et al. (2016). On the other hand, results suggest that game quality seems to have no significant effect on platform installed base (and consequently in platform sales) which might indicate that consumers are more interested in other factors rather than game quality when deciding to adopt a video game platform.

Steiner et al. (2016) found that the video game console market is strongly fragmented. Their survey-based study found that, when deciding to adopt a platform, the segments of hardcore and habitual game consumers consider game quality over other factors. However, they also found that the largest segment is of the casual game consumers, which do not show a specific preference of any game-related factor including game quality and game variety when choosing a video game platform. Indeed, in a study of several platform industries, Stremersch et al. (2007) found that platform sales affect complement variety, but the other way around was not common. Hence, there might be other factors rather than game quality and game variety that attract most of video game consumers.

In the seventh generation of video games, it was clear, due to the differences of technical architecture between platforms, that the Nintendo Wii did not compete in graphics with its rivals. Instead, it focused in giving a totally new gaming experience to its consumers by introducing the *Wiimote*, a remote controller based on accelerometers and infrared sensors. It allowed players to, for example, play a tennis video game by moving their arms and body to mimic the real serve of a tennis player. This made possible the development of more playable and enjoyable games for less expert players. That is, the introduction of the Nintendo Wii

managed to attract a new niche segment of less skilled players and let the entire family play sports, exercise, and interact with one another without requiring expert skills (NORMAN and VERGANTI, 2014). This indicates that the perception of innovativeness and easiness in playing games by the eyes of the consumers may have been paramount for the Wii to attract most of the casual consumers in the market and to lead the industry for most of the time in the seventh generation even with a less advanced technical architecture compared its generation rivals. This might explain why the Wii amassed the highest installed base in the generation even though it presented the smallest average exclusive game quality. Hence, the perception of innovativeness and easiness might be a factor that video game consumers prefer over game quality and game variety when choosing a video game platform and future studies should further investigate this.

The results of this study also suggest that the platforms with more advanced technical architecture in terms of main components (CPU, GPU, and RAM) present higher exclusive game quality compared to their rival platforms. This suggests that more advanced technical architecture allows video game developers to build exclusive games with better graphics, frame rate, resolution, and so forth, which may directly impact game quality.

However, what is interesting is that the platform that presented the most advanced technical architecture and highest average exclusive game quality (the PlayStation 3) was the platform that presented the smallest installed base compared to its rivals in the generation. Even though the PlayStation 3 presented the best components in terms of CPU, GPU, and RAM in the seventh generation, according to Cennamo et al. (2018), it was the console that presented the most complex technical architecture when compared to its rival platforms. That is, it was harder to develop games for the PlayStation 3 than for the other platforms of the generation. This might have harmed the variety of game titles offered in that platform. As seen in Figure 2, the PlayStation 3 was the console that offered the smallest exclusive game title variety for most of the time in the seventh generation. Also, compared to its rivals, the PlayStation 3 was the platform that was released in the U.S. market with the highest price: $499 for its cheapest model. In comparison, when the Xbox 360 and the Wii were released in the market, the cheapest model of each platform were sold by, respectively, $399 and $249. Together, these factors might explain why the PlayStation 3 was the platform that sold less in the generation in the U.S. market.

Besides, results suggest that platform maturity have a negative impact in the quality of exclusive game titles. This might happen because, when a new video game generation is born,

the difference of game performance in terms of graphics, screen resolution, and so forth, in comparison with the previous generation is likely to be substantial. Hence, consumers might overestimate the quality of games released in the beginning of the new generation because they were used to play games for some consecutive years with a smaller game performance in the previous generation. This may make games released in the beginning of the generation to be reviewed with higher scores. As the platforms of the new generation mature, this biased game quality perception might fade away, which may diminish the review scores of games released along the generation. That is, even if the game developers manage to increase game performance by exploiting the full potential of the console hardware due to their higher knowledge about the platforms technical architectures, this increase in game performance might not be so perceptive by the eyes of the consumers when compared to the difference of game performance across generations, which might harm the game quality perception as the platforms mature.

Furthermore, platform producers rely on large-scale successes right on the beginning of the platform life to rapidly seek adopters (WILLIAMS, 2002). To do so, platform producers start developing the next generation platforms when the current ones are reaching maturity in order to present their technical architecture specifications to game developers. With that, game developers can build game titles for the forthcoming generation platforms even before the latter ones are introduced in the market. Because video game platforms are useless without complementing games (STEINER et al., 2016), this allows the forthcoming generation platforms to be introduced in the market in conjunction with some compatible game titles. Thus, when platforms of the current generation are reaching maturity, it is possible that game developers are building games not only for the platforms of the current generation but also for the platforms of the forthcoming generation. With their efforts and resources split between different game developments at the same time for platforms of different generations, the quality of games released in the late stage of the current generation might be negatively impacted due to game development resources constraints, which might also explain why results showed that platform maturity is negatively associated to game quality. Future studies should further investigate this.

The results of this study lead to some implications. First, platform producers should follow one clear competition strategy to attract target niches of consumers. For example, they have to decide if they will compete in graphics performance by introducing platforms with cutting-edge technical architectures to attract most expert players, or if they will compete in

novel gaming experience to attract more casual and unexperienced players. If following both strategies in the same product incur in higher platform price, it could not be beneficial because higher prices might harm platform sales.

Second, if the platform producer decides to compete in graphics, it should invest not only in cutting-edge technical architecture to deliver high-quality graphics but also make it easy for complementors to develop games for their platforms. That is, the platforms technical architectures should be more advanced or at least similar to their direct competitor platforms in the generation to allow the development of games that present similar, or even better, quality in terms of graphics, resolution, quantity of colors, and so forth. At the same time, platform producers should provide a platform with a technical architecture in which game developers do not face difficulty in developing games for the platform, in a way to stimulate game title variety. Also, the technical architecture of platforms should not be too complex in a way that the platform price is substantially higher than of its rivals, which would harm platform adoption.

Finally, platform producers need to find a balance in the timing of when to start developing successors platforms for forthcoming generations. That is, this timing should not be too early in a way that game developers have to split their game development resources between the current and the forthcoming generation for a longer time, which may harm the quality of game released in the final years of the current generation. Also, because complementors need time to learn how to develop games to the forthcoming platforms, this timing should not be too late in a way to give very short time to game developers to build games for the forthcoming generation, which would harm the quality of games released in the early stage of the new generation.

The main contribution of this study is to empirically assess if platform installed base and complement quality, in the video game platform industry context, influence each other in a positive feedback loop way. Results suggest, though, that the direction of influence happens only from platform installed base to game quality. This result is similar to what Stremersch et al. (2007) found between platform sales and complement variety, in which platform sales influenced complement variety, but the other way around was not common. In addition, by assessing also the effect of platform maturity and platform technical architecture on complement quality, this study contributes to the literature by shedding new light on a major gap about what influences complement quality of platforms, in which empirical evidence was still scarce in the literature.

This study is not free of limitations, though. The results of this study suggest that, in the video game industry, the development of high-quality complements is associated to the technical architectures of the competing platforms in a same generation. This may not be true for other content-delivery platforms such as YouTube and Netflix. For example, most of the video streaming platform services require access through computers, notebooks, smartphones or smart TVs, which do not need to have cutting-edge technical architectures to be capable of providing the platforms services. For this, these devices need to have basic components and access to the internet. Hence, for these platforms, the quality of their content is not supposed to be better if the technical architecture of the accessing device is also better. Thus, the generalization of the results of this study to other platform industries should be done with care. In addition, the sample of this study comprises only one generation of video game platforms. To date, the current video game generation is the eighth, in which platforms have not yet completed their lifespan. As the forthcoming generations of video complete their lifetime, future studies should investigate if results also hold for other generations of video games.

Future studies should also further investigate what drives the perception of quality of complements of other types of platform services and products. Each platform market has its own specificities that may differ from one to another. In addition, specifically in the video game industry, the perception of innovativeness and easiness of gaming experience by the eyes of the consumers, which may impact the perception of complement quality and platform adoption, should be also further investigated. Also, future studies could investigate how game quality is impacted by game development budget, a variable that is supposed to influence the quality of platforms complements but empirical studies are still scarce in the literature. Additionally, because this is the first study to assess a reverse causation effect between platform installed base and complement quality, future studies could apply alternative models, as the ones discussed by Leszczensky and Wolbring (2018), for example, for reverse causation assessment between those variables.

In conclusion, platform producers should follow one clear competition strategy to attract target niches of consumers. Also, platforms should present an environment in which complements are easily incorporated to the platforms' cataloge in order to increase complement variety and quality. Moreover, platform price seems to be important for platform adoption. Thus, platforms that follow the same competition strategy are supposed to compete also in price, as, all else equal, more expensive platform services or products tend to sell less than cheaper platform rivals.

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