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The influence of developer multi-homing on competition between software ecosystems

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ABSTRACT

Having a large number of applications in the marketplace is considered a critical success factor for software ecosystems. The number of applications has been claimed to determine which ecosystems holds the greatest competitive advantage and will eventually dominate the market. This paper investigates the influence of developer multi-homing (i.e., participating in more than one ecosystem) in three leading mobile application ecosystems. Our results show that when regarded as a whole, mobile application ecosystems are single-homing markets. The results further show that 3% of all developers generate more than 80% of installed applications and that multi-homing is common among these developers. Finally, we demonstrate that the most installed content actually comprises only a small number of the potential value propositions. The results thus imply that attracting and maintaining developers of superstar applications is more critical for the survival of a mobile application ecosystem than the overall number of developers and applications. Hence, the mobile ecosystem is unlikely to become a monopoly. Since exclusive contracts between application developers and mobile application ecosystems are rare, multi-homing is a viable component of risk management and a publishing strategy. The study advances the theoretical understanding of the influence of multi-homing on competition in software ecosystems.

1. Introduction

Competition in the mobile communication industry has been argued as turning from "a battle of devices to a war of ecosystems".[1] Hence, the sheer number of applications in the marketplace has become increasingly important in marketing new mobile devices (see e.g., Chen, 2010; Reuters, 2012; Lee, 2015; Smith, 2015). All leading mobile operating system providers have established application marketplaces such as Google Play, App Store by Apple and Microsoft's Windows Phone Store (previously Windows Phone Marketplace) with the aim of enticing a large number of content providers (e.g., application developers) in order to create their mobile application ecosystems. The logic behind establishing the ecosystems is grounded on the theory of network externalities (Katz and Shapiro, 1985). Due to network externalities, a large number of application developers within the ecosystem is expected to lead to a large number of applications that, in turn, will attract customers and drive device sales, leading to a virtuous circle (Holzer and Ondrus, 2011).

In this study, the concept of 'mobile application ecosystem' refers to "an interconnected system comprising an ecosystem orchestrator, mobile application developers, and mobile device owners, all of whom are connected through a marketplace platform" (Hyrynsalmi, Seppänen and Suominen, 2014). Hence, a mobile application ecosystem is a derivate of the more general concept of a 'software ecosystem' (Jansen, Finkelstein, and Brinkkemper, 2009; Bosch, 2009; Manikas and Hanssen, 2013).

The emergence of ecosystems has increased the complexity of revenue models, but also cooperation, competition and co-opetition between and within the ecosystems. The traditional value chain approaches (Porter and Millar, 1985; Porter, 2004), employed to describe the telecommunications industry (Barnes, 2002; Maitland, Bauer, and Westerveld, 2002; Funk, 2009), have been increasingly replaced by ecosystem approaches (Basole and Karla, 2011, 2012; Basole, Russel, Huhtamäki, and Rubens, 2012).

The increased complexity calls for a better understanding of the boundaries and structures of the ecosystems (e.g.,

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[1] Stephen Elop, the former Executive Vice President of Microsoft's Devices and Services and (at the time of the comment) the CEO of Nokia Corporation, speech at D9, June 1, 2011

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Jansen et al. 2009; Gueguen and Isckia, 2011; Hanssen, 2012). Prior research has investigated the success factors of the iPhone (Laugesen and Yuan, 2010; West and Mace, 2010), the distribution and capture of value in the mobile phone supply chains (Dedrick, Kraemer, and Linden, 2011), developers' perspectives on the mobile application markets (Lee, Lee, Shim, and Choi, 2010; Holzer and Ondrus, 2011; Schultz, Zarnekow, Wulf, and Nguyen, 2011), the dynamics of the application marketplaces (Järvi and Kortelainen, 2011; Hyrynsalmi, Suominen, and Seppänen, 2013; Jansen and Bloemendal, 2013), standard wars and platform battles (Heinrich, 2014; Gallagher, 2012; van de Kaa and de Vries, 2015; van de Kaa, van den Ende, de Vries and van Heck,. 2011) and cooperation within ecosystems (Gueguen and Isckia, 2011). However, there is a dearth of theoretically grounded literature offering foresight on the competition between software ecosystems that could guide mobile application developers to optimize their publishing strategies.

To fill this void in the literature, this study draws on theory about platform competition (Rochet and Tirole, 2003; Armstrong, 2006; Sun and Tse, 2009) and investigates application developers' multi-homing (i.e., the situation in which developers publish applications in two or more ecosystems) as well as the content of the most downloaded applications. According to the extant research, the success of network platforms, such as mobile application ecosystems, is determined by whether the market is single-homing or multi-homing in terms of volume (Sun and Tse, 2009). In other words, if application developers prefer to offer their products in one ecosystem, i.e. single-home, the market as a whole will, over time, develop into a monopoly of the leading ecosystem.

To gain a more accurate insight into the competition between software ecosystems, we advance the research on the influence of multi-homing on platform competition in two-sided markets (Sun and Tse, 2009). Software ecosystems are two-sided markets since two groups of agents, e.g. consumers and application developers operate in the market. Second, we contribute to the research on competition dynamics in the telecommunications industry (He, Lim, and Wong, 2006). Our point of departure is that, because only a small number of all applications available in the ecosystems are actually actively used by customers, consequently only a small number of all developers generate the majority of downloads. Thus, we particularly focus on the role of this group of developers that we define as '*nucleus developers*' since they have a central role in the success of an ecosystem. Hence, we shed light on the bargaining powers of the nucleus developers and ecosystem orchestrators such as Apple, Google, and Microsoft that host and maintain the ecosystems (Manikas and Hansen, 2013).

Against this backdrop, we empirically study more than one million applications from all three mobile application ecosystems, examining the level of multi-homing at the levels of the (1) mobile application ecosystem and (2) nucleus developer. We use web crawling to collect the data, and string matching algorithms to pair applications and developers of different ecosystems. We then move to examining how the dynamics of multi-homing change by analyzing the nucleus developers to determine whether they are particular to multi-homing and, thus, less dependent on a single ecosystem orchestrator. Finally, we investigate the content of the most successful applications and show that the content, i.e., the value propositions of the most popular applications can be classified into a relatively small number of categories.

Our results demonstrate that just three percent of the developers generate more than 80% of all installed applications. In addition, the results show that when regarded as a whole, only a small subset of application developers multi-home. However, among the nucleus developers, multi-homing is common. This indicates that mobile application ecosystems can be considered both single-homing and a multi-homing market depending on the level of analysis. We term markets like these '*multilevel two-sided markets*'. Taken as a whole, our results offer an explanation as to why several competing mobile application ecosystems can co-exist. For professional application developers, who have the resources to publish their applications in multiple ecosystems, this study implies that multi-homing is a viable component of risk management and a publishing strategy.

The remainder of the study is structured as follows. After this introductory section, we present the theoretical foundation of the study. The third section includes the methodology and data collection process. The results are presented in the fourth section. The fifth section comprises discussion on the results, implications for research and practice, and also limitations and avenues for further inquiry. The last section concludes the study.

2. Background

The number of application developers in mobile application ecosystems generally increases the number of applications available in the marketplace and, hence, the value of the ecosystem to the customer, and vice versa (Holzer and Ondrus, 2011; Cenamor, Usero and Fernandex, 2013). Therefore, it is paramount for ecosystem orchestrators to involve both customers and developers in their respective ecosystems. Thus, the success of an ecosystem is dependent on both developers and customers. As a result, mobile application ecosystems can be termed 'two-sided markets' (Rochet and Tirole, 2003; Armstrong, 2006).

Two-sided markets are economic platforms with beneficial cross-group network effects (Armstrong, 2006; Rochet and Tirole, 2003; Parker and Van Alstyne, 2005). In other words, the value of participating in a platform for agents in one group depends on the number of participants in another group. Network effects can accrue from direct externalities, whereby utility increases as the number of users consuming increases; and indirect externalities, whereby the demand for a product depends on the existence of another product (Katz and Shapiro, 1985). Hence, in the mobile application ecosystems context, two-sided markets can be conceptualized as markets where one or several economic platforms enable interaction between customers, developers, and an orchestrator (Rochet and Tirole, 2003, 2006; Armstrong, 2006).

To date, the managerial and scholarly debate on two-sided markets has followed the logic of the credit card business, where the absolute number of merchants accepting a credit card — or the number of applications available in the marketplace — determines the value of the credit card for the end user (see e.g., Chen, 2010; Reuters, 2012; Lee, 2015; Smith, 2015). However, this approach considers all applications equal and thus ignores the qualitative aspects of the market dynamics. Prior studies have examined winner-takes-all competition (Eisenmann, Parker and Van Alstyne 2006), i.e., a situation where one platform ultimately wins the platform race. Econometric modeling studies, such as Tse (2006) and Sun and Tse (2009) have created models of platform competition that emphasize the role of single- or multi-homing

As there are several competing mobile application ecosystems, customers and developers can participate in more than one ecosystem. Participation in more than one economic platform at a time is termed 'multi-homing' (Rochet and Tirole, 2003; Armstrong, 2006; Sun and Tse, 2009). Multi-homing in two-sided markets is a situation where more than one two-sided platforms exist in the same market, and the two sides of the market (e.g., buyers and sellers) are free to operate in several platforms. For example, an application developer is multi-homing when it offers products in both the Apple App Store and Google Play. Similarly, a customer is multi-homing when he/she utilizes several mobile devices operating in different platforms; however, with a single mobile device, the customer can typically participate in only one ecosystem. Single-homing is the opposite situation: an actor participates only in one ecosystem.

Sellers engage in multi-homing to gain access to larger potential markets (Rochet and Tirole, 2006), to offer their products to the same customers across different platforms, and to reduce dependency on a single market and orchestrator (Idu, van de Zande, and Jansen, 2011). However, multi-homing also generates costs associated with converting a product to different platforms, additional marketing efforts, and also maintaining the product for several platforms (Eisenmann et al., 2006).

Prior research has focused on software vendors' multi-homing in console games marketplaces (Landsman and Stremersch, 2011), Software as a Service (SaaS) marketplaces (Burkard, Draisbach, Widjaja, and Buxmann, 2011; Burkard, Widjaja, and Buxmann, 2012), and also within Apple's ecosystem (Idu et al., 2011). In their study on the gaming console market, Landsman and Stremersch (2011) found that the multi-homing of games has a negative effect on sales at the marketplace level, although the negative effect decreases when a platform matures or gains market share. Idu et al. (2011) investigated the iPhone, iPad, and Mac software marketplaces, and found that, out of the top 1,800 applications, 17.2% were multi-homed in two marketplaces and 2.1% in all three marketplaces.

In their theoretical analysis of competitive advantage in two-sided markets, Sun and Tse (2009) highlighted the importance of the distinction between multi-homing and single-homing in determining the winner among competing platforms. Drawing on dynamic systems models, Sun and Tse (2009) argued that, in the context of single-homing, only the largest network will survive and that network size is the critical factor in determining the winner among competing platforms. This is due to the fact that in a two-sided market, network participants become a critical resource for the platform orchestrator (Sun and Tse, 2009). By drawing on two dynamic systems models, Sun and Tse (2009) concluded that a multi-homing market is able to sustain several platforms, whereas a single-homing market is prone to becoming dominated by a single platform.

However, Sun and Tse (2009) pointed out that their analysis of platform competition focused on the quantity of network participants but did not address the quality of participants. This issue is particularly important in the context of mobile application ecosystems, since most of the installations in Google Play were generated from a small set of applications (Hyrynsalmi, Suominen, Mäkilä, and Knuutila 2012).

In the following section we pay special attention to this subset of applications as well as their developers. In doing so, this study moves beyond a volume driven analysis of ecosystem competition to analyze the value propositions made within different platforms and to uncover single- or multi-homing patterns at a value proposition level rather than a developer level.

3. Research process

We collected two datasets for this study: (1) the data of over million applications available in the marketplaces of the three major mobile application ecosystems (described in Section 3.1); and (2) the most popular applications in these marketplaces (Section 3.3). The first set of data is used to study the overall multi-homing rates in the market while the second set gives us an insight into the top applications and their developers. We analyzed the empirical data in three stages. First, we identified the multi-homing of all applications and developers from the three marketplaces (Section 3.2). In the second stage, we analyzed the multi-homing patterns of the nucleus developers (Section 3.3.). In the third stage, we conducted a content analysis of the nucleus developers' applications to determine whether they could be classified into qualitatively similar content categories.

3.1. Application data collection

In total, empirical data were collected on 1,295,320 applications from the three ecosystems, Google Play, Apple's App Store, and Windows Phone Store, during December 2012 (Windows Phone Store) and January 2013 (Google Play and Apple App Store). Our data shows that Apple's App Store had 654,759 applications made by 149,032 developers, Google Play had 542,955 applications made by 88,144 developers, and Windows Phone Store had 94,606 applications made by 25,833 developers.

We employed a web crawler[2] (see e.g., Castillo, 2004; Olston and Najork, 2010) utilizing the Python programming language to gather the application data. The script began from the front page of each marketplace and went through all of the listed pages. It stored all the application identifiers — available on each web page — into a queue of applications to be studied. Duplicate values were removed from the queue. The program also collected various attributes for each identified application from their public profiles in the marketplace, which were stored in a database. Although the available information varied in each marketplace, as a minimum, the name, developer, and price of each application were captured.

3.2. Detecting multi-homing

Following Landsman and Stremersch (2011), we investigated multi-homing by dividing it into two levels: seller- and platform-level multi-homing. Seller-level multi-homing is a situation where a particular seller (i.e., developer) offers its products to customers in more than one ecosystem. Platform-level multi-homing takes place when a particular application is available in several ecosystems. A developer can publish different products in different ecosystems, and a particular product can be published on different platforms by different developers. The latter is a quite common approach in, e.g., video game markets where the porting of a popular video game from one console to other is carried out by another game studio. In mobile application ecosystems, there are a few similar instances. For example, Microsoft Corporation is the publisher of the Facebook application in the Windows Phone ecosystem and Research in Motion Limited is the publisher of the Facebook application in the Blackberry World (previously Blackberry App World) marketplace, which reveals that the actual implementation of front-end applications was performed by third-party developers (i.e. by the orchestrators themselves in these cases). Respectively, Facebook and Facebook Inc are the publishers of Facebook applications in the Android and iOS ecosystems.

We implemented a set of Python scripts to identify multi-homing developers (i.e., seller-level multi-homing) and applications (i.e., platform-level multi-homing). We utilized two matching strategies, namely exact matching and approximate matching. Exact matching requires that the two names under comparison are the same, character by character. However, the comparison is case-insensitive. Approximate matching allows a particular level of dissimilarity in the names under comparison. This strategy is useful in situations where, for example, a developer has employed pre- or postfixes such as 'Inc.' or 'GmbH' in one marketplace but omitted them in another. For example, 'Rovio' is the publisher of Angry Birds in Windows Phone Store, while 'Rovio Mobile Ltd.' is the publisher in Google Play and the Apple App Store. We used Levenshtein distance (Levenshtein, 1966) to measure the similarity of two names and employed Python's difflib library[3] for comparisons.

We decided to utilize these two matching strategies because the exact matching gives the lower bound for the total number of multi-homing cases but misses some cases as discussed above. The approximate matching, in turn, detects these cases but can also create false positive matches. We iterated different similarity thresholds in the approximate matching process until there was a clear increase in false positive matches that was determined via visual examination.

[2] The scripts will be made available to other researchers by contacting the corresponding author.

[3] Python v2.7.3. documentation – http://docs.python.org/library/difflib.html

Table 1
Platform-level multi-homing in three application ecosystems.

	In all three ecosystems	Apple App Store & Windows Phone Store	Google Play & Windows Phone Store	Google Play & Apple App Store	Share of multi-homed applications
Exact	430	1,092	1,886	16,578	1.7%
Approx. (85%)	531	1,348	2,184	21,153	2.1%
Approx. (75%)	645	1,586	2,464	24,598	2.5%
Approx. (50%)	1,453	2,698	3,963	30,930	3.2%

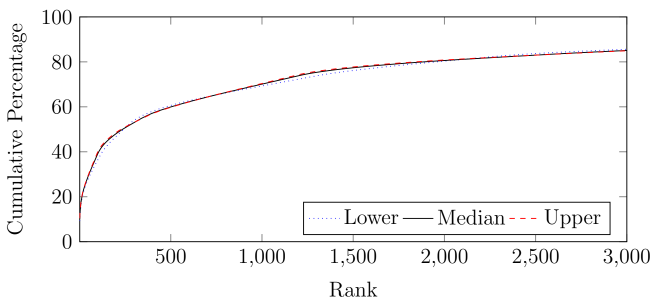

Fig. 1. Cumulative percentages of application installations in Google Play for the top 3,000 developers (3.3% of all developers) with three estimation methods (lower bound, median of bounds, and upper bound).

For each iteration, we randomly selected a dozen of the paired applications and examined whether the created pairs were correct. As a result, the approximate matching offers an upper bound for the number of multi-homed applications. The actual number of multi-homers falls within this interval.

3.3. Data collection of ecosystem nucleuses

As pointed out by Hyrynsalmi et al. (2012), most of the installations in Google Play were generated by a small set of applications. Therefore, we pay special attention to this subset of applications, also referred to as 'superstars' (Landsman and Stremersch, 2011), and we consider developers of these superstar applications as the 'nucleus developers' of the respective ecosystems. It should be noted that while a keystone actor, i.e. "an active leader in the ecosystem" (Basole, 2009), can also be a nucleus developer, the opposite is seldom the case.

To examine the nucleus developers' role in the ecosystems, we examined the 3,000 developers' cumulative shares of the total number of application downloads in the Google Play application marketplace.

We calculated the number of installations from the application dataset — taken from the web crawling of Google Play — with estimated lower and upper bounds and also median values. That is, when an application's installation category is '5-10', values 5, 10, and 7 were respectively employed as the installation counts. [4] Fig. 1 below clearly shows that the top 3,000 developers (3.3% of all) of developers generate the majority (i.e., 85.0 to 85.6%) of all installations in the marketplace. As can be seen from the figure, this finding holds with all three estimation methods. Furthermore, the top 25 developers alone account for approximately one-fifth of all downloads in the marketplace.

As drawing an exact line between the superstars and other highly successful applications is problematic and because not all marketplaces publish information regarding installation or download counts, we decided to utilize the top 100 application listings as a proxy that gives a relatively good estimate of the superstar applications. The marketplaces publish different top application listings freely in their webpages. [5] For example, all marketplaces offer a list of the most installed free applications.

We examined the top 100 application listings from free and paid applications for each marketplace. Furthermore, for Google Play and the Apple App Store, we also examined the top grossing listings that — in addition to revenue earned from direct sales — also includes revenues earned from different in-application payments. We collected information on 622 unique applications from the overall top 800 applications, and then manually determined whether the producers of these applications were present in several ecosystems. In concrete terms, we manually investigated the profile information of these applications in the marketplaces, on the developers' web pages and in press releases as well as newspaper and magazine articles about the developer to detect whether the developer was multi-homing.

4. Results

This section presents the findings of the study. First, we show the overall level of multi-homing among all applications. Second, we focus on application developers and examine their multi-homing behavior. Third, we investigate the multi-homing rates of superstar applications and nucleus developers. Fourth, we analyze the content of these superstar applications and their value propositions.

4.1. Platform-level multi-homing

The results demonstrate that the share of multi-homed applications from the overall number of applications is small. Table 1 shows the results of platform-level multi-homing with exact and approximate matching strategies, and also the results of three similarity threshold values for approximate matching.

Although the number of multi-homed applications doubles when the similarity requirement is loosened, the overall share of multi-homed applications still varies from only 1.7 to 3.2% of all applications. For a single ecosystem, the number of multi-homed applications varies only a little: 2.6 to 4.9% for Apple App Store, 2.6 to 5.3% for Windows Phone Store, and 3.3 to 6.2% for Google Play. Similarly, the number of applications available for all three ecosystems remains under 0.14% in all cases.

We tested different similarity requirement values and found that 50% similarity was the lowest without a clear increase in false positive matches. Nevertheless, the share of multi-homing applications remained low; for example, 3.5% of all unique applications with a threshold value of 40%. In sum, our results demonstrate that the multi-homing publishing strategy is only employed by a small number of developers and, typically, for only a small set of applications.

Google Play and Apple App Store host the majority of multi-homing applications, which is not surprising as the two ecosystems have larger volumes of applications and developers than Windows Phone Store. Interestingly, however, almost three times more developers have published in both Google Play and Windows Phone Store than in Apple App Store and Windows Phone Store. This observation might be due to the different publication processes utilized by

[4] Application marketplaces do not offer information about the exact number of installations.

[5] See e.g. http://www.windowsphone.com/en-us/store/top-paid-apps for the Windows Phone Store's top purchased applications.

Table 2
Percentages of platform- and seller-level multi-homing utilization in different top 100 listings in three ecosystems. The top grossing listings includes applications that have the highest in-application sales.

		Platform-level	N	Seller-level	N
Apple App Store	Free	48.0%	100	55.2%	87
	Paid	45.0%	100	42.3%	71
	Grossing	50.0%	100	62.0%	71
	Total	47.0%	253	50.3%	175
Google Play	Free	55.0%	100	60.0%	80
	Paid	43.0%	100	42.0%	81
	Grossing	58.0%	100	69.1%	68
	Total	50.9%	271	51.6%	192
Windows Phone Store	Free	47.0%	100	46.8%	79
	Paid	41.0%	100	43.4%	83
	Total	43.4%	196	43.7%	151

N = number of applications and application developers in each listing. Windows Phone Store does not publish the top grossing listing.

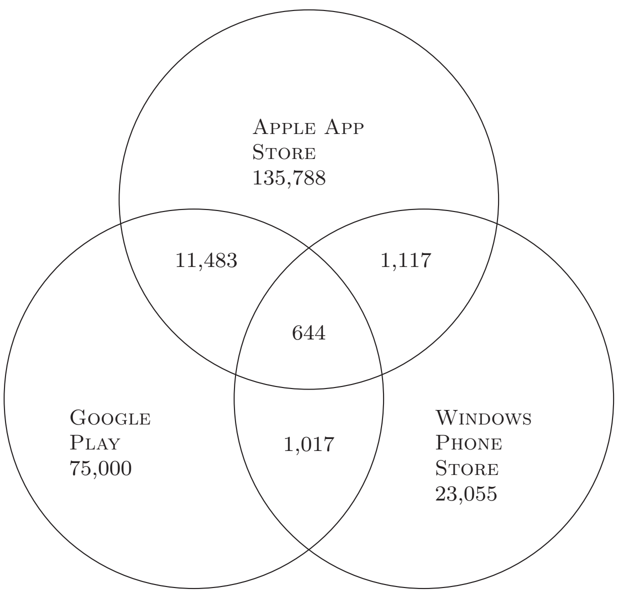

Fig. 2. Venn diagram of seller-level multi-homing, based on the exact matching strategy, in three application ecosystems.

the orchestrators (Campbell and Ahmed, 2011; Cuadrado and Dueñas, 2012) as Google Play and Windows Phone Store have more open acceptance processes than Apple App Store.

4.2. Seller-level multi-homing

In brief, the results reveal that seller-level multi-homing is more common than platform-level multi-homing, yet the degree of seller multi-homing is also small. Fig. 2 illustrates the studied seller-level multi-homing in the three ecosystems with a Venn diagram based on the results of the exact matching method. With this matching strategy, we found 248,104 unique developers. From these, 14,261 (i.e., 5.75%) were published in at least two marketplaces, and only 644 (i.e., 0.26%) were published in all three studied ecosystems. For a single ecosystem, the number of multi-homers varies from 8.8% for the Apple App Store to 10.8% for Windows Phone Store and 15.0% for Google Play.

With the approximate matching method, a threshold of 95% raised the share of multi-homers to 7.2% and the share of the developers who work in all three ecosystems to 0.36%. Although the threshold values under 95% found new true positive matches, there was a considerable increase in the number of visually observed false positives.

4.3. Nucleus developers, superstar applications, and multi-homing

To study the superstar applications, we examined eight top 100 applications' listings in the three ecosystems, from which we identified 622 unique applications. Of this group, a considerable share, 244 (i.e., 39.2%), were multi-homed. Table 2 presents the number of multi-homing applications for each studied top list in more detail. These superstar applications were published by 429 application developers, and the number of developers producing the content for each ecosystem is even smaller: the top 800 applications were published by 175 developers in Apple App Store, 194 in Google Play, and by 152 in Windows Phone Store. Out of these 429 developers, a significant number (n = 183; i.e., 42.7%) were multi-homing.

In addition, we studied 100 developers that generated the most installations in the Google Play marketplace (i.e., the top one hundred developers from Fig. 1). Although only 47 of these were in the top applications' developer list, 52 out of 100 developers were multi-homing in at least two mobile application ecosystems. While only Google Play offers these figures, the analysis shows that the magnitude of multi-homing among top developers is similar across the three ecosystems. Finally, when compared to the overall rate of seller- and platform-level multi-homing, the shares of superstar applications and nucleus developers are considerably higher regardless of the employed approach.

In the third and final stage of the analysis, we investigated the content of the superstar applications. First, we examined the 622 applications and wrote a short description of each application and the specific functionality — i.e. the application's value proposition — that the application offers to the user. Thereafter, we classified applications with common characteristics in order to form a category. For example, 'personalization,' 'games,' and 'instant messaging' were defined as categories. This process of analyzing and coding textual data is typical for the content analysis of textual data (see e.g. Krippendorf, 2013). The results of the content analysis are presented in Table 3.

In Table 3, the Game category is by far the largest, containing applications such as Angry Birds and Clash of Clans among others. Facebook is classified under Social Network Service (SNS) front-end and Facebook Messenger under Short message. Instagram is in the second largest category of Photo and video editing. Google Maps and Earth were classified under Maps. Altogether, the majority

Table 3
Classification of superstar applications based on the content provided.

Category	N	Description	Example
Game	367	Classified as games by the developers	Clash of Clans
Photo and video editing	36	Offer different kinds of effect and editing option for videos and/or photos	Instagram
Personalization	34	Change user interface elements; e.g., backgrounds, ring tones	Superuser Elite
SNS front-end	19	Front-end for social network services for e.g., Twitter, Facebook	Facebook
Music/video player	18	Applications that play music and/or videos	Spotify
Assistant, calendar, & notes	16	Small tools utilized to help everyday life; e.g. reminders, listing tools	MyCalendar
Mobile front-end for Internet content	15	Specific front-ends for web content such as Wikipedia	ESPN, SportsCenter Feed
Short message	11	For sending and receiving short messages	WeChat
Shopping front-end	10	Mobile specific front-ends for e-Shopping services	Ebay
VoIP service	8	Voice-over-IP applications	Skype
Flashlight	8	Flashlight applications	Flashflight Free
Office	7	Office-like applications	TurboScan
Maps	6	Offer different map services	Google Maps
Weight loss	6	Offer weight tracking and tips for weight loss	Weight Watchers Mobileloss
Sleep application	6	Plays music that should help one to sleep	Sleep Bug Pro
Book-on-demand reader	5	Readers for book-on-demand services	iBooks
Voice recognition	4	Utilize voice recognition	SoundHound
Dictionary & translate	4	Dictionary and translating applications	Translator
Sport tracker	4	For tracking sport activities	Endomondo Sports Tracker Pro
Dating	3	Dating services	MeetMe
Search	3	Different search services	Google
Cloud storage	3	Enables saving and retrieving content from cloud services	Google Drive
Music making	2	For playing and recording music instruments	GarageBand
Bank front-end	2	Front-ends for banking services	Bank of America
Backup	2	Enables storage and retrieval of phone data	My Backup Pro
Barcode reader	2	For reading barcodes	Barcode Scanner
AR applications	2	Augmented reality applications	Sky Map Free
Misc.	19	Applications that could not be merged with any other application to form a category	Accurate Tuner Pro
Total	622		

N = number of occurrences.

of applications were easily classified into the categories and only 19 applications were put into the miscellaneous category, containing applications such as GasBuddy, Official eBay Android App and Longman Dictionary.

The content analysis revealed that the majority of the superstar applications (i.e., 59%) were different kinds of games. In addition, there were rather specific categories among the superstar applications. For example, the listing includes eight different applications that turn a phone into a flashlight and six applications that play sounds that aim to help send a user to sleep. Interestingly, we did not observe any major differences between the three competing ecosystems as the relative percentages of the categories are similar among each of the three mobile application ecosystems.

In summary, the majority of the most popular content, such as Facebook, weather apps and the most popular games, is either offered by the original developers or imitated by other developers in all three ecosystems. That is, the levels of multi-homing among superstar applications and nucleus developers are rather high. This observation contrasts with prior studies that suggested that the level of multi-homing is, at most, small (Boudreau, 2007, 2012). Altogether, our results have several implications for both research and practice that are discussed in the following section.

5. Discussion

This section presents the key findings of the study. Thereafter, we compare our results against prior theory on multi-homing in two-sided markets (Sun and Tse 2009), and then on the often-stated argument concerning the importance of a large developer base and the volume of complementary products to the success of an ecosystem (Cenamor et al., 2013). This is followed by a discussion, from a more practice-oriented perspective, on the effect of multi-homing on the competition between software ecosystems. We conclude by discussing the limitations of the study and offering avenues for further research.

5.1. Key findings

We have condensed the results of the study into three key findings:

1. When looking at the market as a whole, mobile application ecosystems are single-homing markets.
2. However, when focusing only on the most downloaded applications we find that the mobile application ecosystems are multi-homing markets.
3. The value propositions of the superstar applications are relatively similar across the ecosystems.

First, our results imply that when looking at the market for mobile applications as a whole, it is a single-homing market. As indicated by our results from both the platform- and seller-level multi-homing subsets, only a small set of applications (i.e., 1.7 to 3.2%) and developers (i.e., 5.8 to 7.2%) are multi-homing.

Second, when looking at the most popular applications and the developers of these applications, the market is a multi-homing market. Our results indicate that multi-homing rates among the most popular applications, that is, superstars (i.e., 39.2%) and their nucleus developers (i.e., 42.7%), are almost ten time that of their competitors when compared to all other applications and developers in the market.

Third, our content analysis of the superstar applications in all three mobile application ecosystems offers empirical information on the value propositions in the mobile applications market. Our results show that superstars are largely basic applications such as flashlight and short message services. Furthermore, a considerable share of these applications are actually only front-ends for services offered on the web, which implies that third parties can replicate the content of many superstar applications with relative ease. In addition, our analysis of superstar applications indicated that the actual set of nucleus developers appears to be rather small and is mainly comprised of game producers.

5.2. Theoretical implications

Our study accumulates understanding on software ecosystems in three areas. First, our research offers novel insight into the influence of multi-homing on competition between ecosystems. Our findings indicate that the level of multi-homing differs considerably between the overall market and superstar applications. According to Sun and Tse's (2009) theory of platform competition, a multi-homing market can sustain several competing ecosystems; however, a single-homing market eventually evolves into only one prevailing ecosystem. When examining multi-homing at the level of the whole content of the three ecosystems, our findings support Sun and Tse's (2009) assertion that the market would evolve into one dominant ecosystem.

At the same time, our results also indicate that multi-homing is much more common for superstar applications and nucleus developers. According to Sun and Tse (2009), this implies that the market would be able to sustain more than one ecosystem. Overall, our research advances Sun and Tse's (2009) model of platform competition by emphasizing that multi-homing can manifest differently within a single group of actors in the market. However, further work is needed to understand multilevel two-sided markets in which the actors' multi-homing behavior and their value for the ecosystem differs substantially between the small number of nucleus developers and the vast majority of developers.

Second, our findings demonstrate that the quality of application developers is far more important than their number. As our results show, only 3% of application developers are responsible for more than 80% of installations in a single ecosystem. Hence, after reaching a certain critical threshold, the quality of developers is far more important in terms of generating downloads from the marketplace. Therefore, from the mobile application ecosystem orchestrators' vantage point, attracting and maintaining nucleus developers is far more important than having a large developer base per se.

As a result, we depart from Sun and Tse (2009) who emphasized the sheer size of the two sides of the market as a decisive factor in platform competition. In addition, our findings differ from the extant research (e.g., Yamakami, 2010; Holzer and Ondrus, 2011; Schultz et al., 2011) that, grounded on network externalities (Katz and Shapiro, 1985), somewhat simplistically argues that a large base of developers leads to a large number of applications that, in turn, leads to an increasing number of end-users, and vice versa. As a result, by differentiating between the overall supply of applications and superstar applications, our study offers a more fine-grained view of the competition between mobile ecosystems.

5.3. Implications for practice

First, our observation that nucleus developers are active in multi-homing implies that the market might be able to sustain more than one ecosystem, particularly if the ecosystems are able to focus on specific customer segments and differentiate their offerings (Kouris and Kleer, 2012). This implies that several competing mobile application ecosystems can survive and exist in the future.

Second, our findings imply that application marketplaces are not used to differentiating their ecosystem from that of competitors. The results of the content analysis show that the content of the most installed applications are similar in the three leading mobile applications ecosystems. This supports the findings by Hyrynsalmi et al. (2013) who did not find differentiation between the consumers nor the application offerings of the ecosystems. In addition, our analysis of the content of the most downloaded applications emphasizes the importance of games for attracting users to the marketplace.

As a result, the similar value propositions in all three major mobile application ecosystems support the existence of multiple platforms. This situation is similar to, for example, credit cards, where multiple competing credit card companies with very similar value propositions co-exist. Hence, the mobile application marketplaces are thus not a source of differentiation for the different platforms. Future research could investigate whether the mobile application marketplace could be a source of differentiation and how this could be achieved.

Third, based on our empirical findings, we question the number-driven success metrics employed to evaluate mobile application ecosystems (e.g., Gupta, 2012; Reuters, 2012). Furthermore, as pointed out by Hyrynsalmi et al. (2012), only a small share of all applications published in the marketplace are actually downloaded, and even fewer are actually used by customers. In other words, customers are either not interested in, or they do not notice, most of the content available in the marketplace.

As a result, we advise practitioners and researchers to pay increasing attention to qualitative factors that enable the creation of successful application ecosystems (see e.g., Gonçalves and Ballon, 2011; Eaton et al., 2015). In addition, we suggest ecosystem orchestrators and industry analysts move from counting the number of developers in the market toward evaluating the value of each developer.

Fourth and finally, our results further imply that nucleus developers' bargaining power over ecosystem orchestrators is likely to increase in the future. This is due to the fact that a few nucleus developers create the applications that constitute the majority of installations in the application marketplace. Hence, attracting and sustaining nucleus developers is essential for maintaining an ecosystem's competitiveness.

The ecosystem orchestrators can try to compensate for their lack of attractiveness among developers by developing popular applications in-house. For example, Facebook applications for Windows Phone and Blackberry have been developed by the ecosystem orchestrators instead of Facebook. Hence, the presence of the application appears to be even more important for the two ecosystem orchestrators than it is for Facebook.

Overall, since multi-homing is a common practice among nucleus developers, creating a clearly differentiated application offering is very difficult for ecosystem orchestrators. For application developers, our results imply that, despite the extra costs for porting the application to other ecosystems, multi-homing seems to be a viable distribution strategy.

5.4. Limitations and future research avenues

As with any other, this study is subject to a number of limitations. First, the data were collected over a short period of time. Second, the data gathering scripts were run from a server located in Finland. Therefore, particular applications that are available only for customers in, for example, the US might not have been shown due to the location of the server we employed. Third, our study also omits competition among multiple application stores serving the same platform. For example, there are several application stores for the Android platform. Due to the lack of porting costs, the competition dynamics between application stores within an ecosystem are different from cross-ecosystem competition, and fall outside of the scope of this study. Fourth, the utilized matching strategies are only approximations of the actual situation.

Fifth, we employed the top application listings as a proxy of superstars. The top listings change over time and are based on download numbers that do not reveal an application's actual level of use. For example, prior survey research indicates that mobile gaming is not of interest to customers (see e.g., Economides and Grousopoulou, 2009; Bouwman, Carlsson, Castillo, Giaglis, and Walden, 2010; Suominen, Hyrynsalmi, and Knuutila, 2014). However, our results show that games form the majority of the most installed applications. This might be a result of a pattern whereby a user downloads several games, tries them all once, and then removes uninteresting ones from the device. Furthermore, it is possible that all applications included in the listings are not real superstars. For example, our data contained eight flashlight applications. Nevertheless, our approach to include all top listed applications can be justified by the fact that we aimed to include all potential superstars. Furthermore, the use of top applications lists omits developers that have many successful applications but lack a superstar. The number of installations for each application is available only on Google Play. We utilized this information and examined these kinds of developers, and demonstrated that the seller-level multi-homing ratio is similar for developers identified based on the listings of the most popular applications and by employing the figures offered by Google play.

Drawing on the implications and limitations of the present study, we suggest three main avenues for future inquiry. First, we have advanced the model of Sun and Tse (2009) on the influence of multi-homing in platform competition in two-sided markets in order to capture the characteristics of mobile application ecosystems. To support the building of theories that illuminate the dynamics of business ecosystems, we encourage further research on different kinds of ecosystems. For example, the video game business shows similar tendencies of being a multilevel two-sided market like the mobile application market (c.f. Landsman and Stremersch, 2011).

With regard to the second area of future research, a business ecosystem should, among other success factors, support niche and opportunity creation (Iansiti and Levien 2004). However, we did not address different aspects of niche creation inside an ecosystem when discussing the numbers of developers and applications. As a result, we encourage further research to create measures for niche and opportunity creation, and to investigate whether the size of an ecosystem affects niche creation and the success of these niches.

Third, future research could investigate whether the large number of applications available in the marketplace adds value to the customer through, for example, increased opportunities to select new products and the pleasure obtained from browsing the selection, or whether a large offering has an adverse effect due to increased search costs.

6. Conclusion

This study assessed multi-homing in mobile application ecosystems with a data of nearly 1.3 million applications from Apple's App Store, Google Play, and Windows Phone Store. The results demonstrate that only a rather small subset of all applications and developers are multi-homing. However, among the most popular applications and their developers, the multi-homing rates are tenfold. Third, we have shown that the value propositions of superstar applications are rather similar between different ecosystems.

The study advances our theoretical understanding of the influence of multi-homing on competition between ecosystems by emphasizing the quality of the proposed content over the sheer size of an ecosystem. The results also indicate that several competing mobile application ecosystems can survive.

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