The Influence of User Feedback on Complementary Innovation in Platform Ecosystems: NLP Evidence on the Value of Multihoming

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Abstract

We study how user feedback affects innovation of multihomed applications within and across platform ecosystems. Therefore, we conduct a quantitative NLP based case study. Our sample consists of 10 multihomed applications with more than 325,000 user reviews on Apple's iOS and Google's Android platform between January and March 2021. We analyze how user reviews translate into functional feature releases of the selected applications within and across platforms. We report three findings. First, we find that about 61% of the functional feature improvements on both platforms were previously demanded by users in the form of user feedback. Second, we show that user feedback of iOS users is more likely to be incorporated compared to Android users' feedback. Finally, we observe that about 10% of feature releases are inspired by cross-platform feedback, providing initial evidence that user feedback from multihoming applications might stimulate cross-platform innovation and enhance the applications' quality and innovativeness.

Keywords: Platform innovation, multihoming, user reviews, platform ecosystems, natural language processing

1. Introduction

In recent years, digital platforms have gained economic relevance and have earned central importance in both society and business environments (Parker et al., 2017; Tiwana et al., 2010). Whereas in traditional businesses, product development is usually conducted within the firm's boundaries, software-based innovation platforms leverage external innovation by opening a core-product to third-parties (Gawer & Cusumano, 2002). Prominent examples from the mobile platform industry include Apple iOS and Google Android. These platforms have experienced an unprecedentedly rapid increase in third-party applications (apps) provided by complementors (a.k.a. developers) which are offered via the platform's integrated marketplace. Such complements determine the value of a platform to a large degree (Ghazawneh & Henfridsson, 2013; Tiwana et al., 2010). Given the importance of complementary innovation and network effects for platform success, platform owners compete for available complementors and consumers (Cennamo & Santalo, 2013; Eisenmann et al., 2011; Parker & Van Alstyne, 2005).

Multihoming, the decision of complementors to participate on multiple platforms at the same time, is becoming increasingly common in platform markets. For example, complementors on Apple iOS may decide to port their apps to Google Android in order to participate on both app markets. Especially in the case of innovation platforms, where complement development requires notable platform-specific development, multihoming may incur significant costs (Cennamo et al., 2018). While multihoming may carry relevant benefits to complementors, such as increased market reach, visibility and strategic diversification, multihoming is often seen as undesired from the perspective of the platform owner (L. Chen et al., 2022; Tiwana, 2013). In particular, research has suggested that complementor multihoming reduces platform differentiation, potentially compromising a platform's dominant position in inter-platform competition (Cennamo et al., 2018; Landsman & Stremersch, 2011; Zhu & Iansiti, 2012). In order to sustain platform differentiation and inter-platform competitiveness, platform owners may thus intent to inhibit multihoming opportunities by increasing switching costs and investing in exclusive contracts (Armstrong & Wright, 2007; Hagiu & Lee, 2011; McIntyre et al., 2021).

Platform markets change the nature of competition by modifying value creation and appropriation (Cennamo, 2021). Complementors on software-based innovation platforms are typically confronted with

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fierce competition with other complementors for market visibility and customer attention (Foerderer et al., 2018). Platforms act as intermediary and, as such, mediate communication of complementors and customers, making user feedback in the form of reviews an extremely important source of insight for understanding changing user needs (Cutolo & Kenney, 2021). Publicly available user reviews on platforms can provide complementors with feedback for their software products (Foerderer et al., 2018). Existing research has proven the insightfulness of analyzing user reviews in the context of software development (Martin et al., 2017). Research suggests that feedback and input of customers is an important part of product innovation (Bosch-Sijtsema & Bosch, 2015), making a user crowd a powerful source for requirements identification for new and improved software features and functionalities (Hoffmann et al., 2020; Maalej, Nayebi, et al., 2016). However, empirical findings on how user reviews translate into new feature introductions by complementors on platforms remain scarce. While an initial study by Palomba et al. (2015) presented preliminary results by linking informative reviews (containing functional and non-functional requirements as well as bug reports) with issues and commits of source code of complementors' new software releases, the current body of research misses thorough empirical findings concerning the impact of end-user suggestions on new and improved features (functional requirements) from the complementor's innovation perspective within and across digital platforms.

In this study, we aim to understand the influence of user feedback on the innovation activity of complementors within and across platform ecosystems. In particular, we consider the origin of user feedback in cross-platform innovation. Due to multihoming strategies of complementors, user feedback may stimulate innovation activities across platform boundaries. The research question of this study is as follows:

RQ: Do complementors leverage user feedback to create new features or feature improvements for mobile applications and does it affect the innovativeness of multihoming applications?

In order to answer this research question, we present the results of a quantitative natural language processing (NLP) based case study on the innovativeness of user reviews in the context of Apple's iOS and Google's Android App Store. Both platforms represent prime examples of the mobile app platform market. We collect data on 10 multihoming complements (i.e., apps that are active in both app stores of Apple iOS and Google Android) with functional updates between January 2021 and March 2021 as well as gather more than 325,000 user reviews released between April 2020 and March 2021. Our dataset enables us to analyze how user reviews translate into feature releases of complements within and across platforms.

Our study highlights the following three findings. First, about 61% of the functional feature improvements of analyzed complements on both platforms were previously demanded by users in the form of user feedback. Second, in our sample, feedback of iOS users was more often incorporated compared to feedback of Android users. Last, about 10 % of feature releases of analyzed complements were inspired by cross platform feedback, providing initial evidence that user feedback from multihoming applications is likely to stimulate cross-platform innovation and influence quality and innovativeness of complements.

2. Background

2.1 Platforms and platform ecosystems

We refer to platforms as "a set of digital resources—including services and content—that enable value-creating interactions between external producers and consumers" (Constantinides et al., 2018, p. 381). In particular, we focus on software-based innovation platforms as a technological core product that provides basic functionality and can be extended by complementary products that interoperate with the platform core (Tiwana, 2013). Platforms act as two (or multi-) sided markets that bring actors together and define the nature of complementarities (Eisenmann et al., 2006; Gawer, 2014; Rochet & Tirole, 2003). While transaction platforms are concerned with the mere facilitation of interactions and transactions among platform participants, innovation platforms provide a technological foundation for complement development (Cusumano et al., 2019). The entity that coordinates access to the platform and develops the underlying platform technology is referred to as platform owner (Cusumano et al., 2019; Eisenmann et al., 2009; Tiwana, 2013). Complementors provide external innovation in the form of complementary products (i.e., complements) to the platform (Parker et al., 2017). The platform owner embraces both complementors and end-users within an innovation ecosystem, in which these independent entities engage in joint development of innovations (Cusumano et al., 2019; Tiwana, 2013; Wang, 2021).

Platforms exhibit network externalities: The platform's attractivity to users is contingent on the number and quality of complements offered (Katz & Shapiro, 1994). Similarly, the platform's attractivity to

complementors depends on the number and suitability of platform users (Parker et al., 2017; Rochet & Tirole, 2003; Tiwana et al., 2010).

2.2 Multihoming in platform markets

Multihoming relates to the strategy of participating on multiple platforms at the same time (e.g., Caillaud & Jullien, 2003; Rochet & Tirole, 2003). Thus, multihoming in platform markets is facilitated by the existence of competing platforms (Armstrong, 2006; Armstrong & Wright, 2007; Caillaud & Jullien, 2003; Rochet & Tirole, 2003). Due to the multi-sided nature of digital platforms, actors from one or more sides of the platform can decide to multihome or instead decide to exclusively affiliate with one single platform (i.e., singlehoming) (Jeitschko & Tremblay, 2020). Examples of multihoming actors on digital platforms include users who maintain affiliations to various platforms (e.g., users of the messaging service WhatsApp who also use Telegram as means of communication) or complementors who develop and maintain services to multiple platforms (e.g., complementors develop apps for both Apple iOS and Google Android). Besides, a platform owner may also multihome first-party complements and appear as complementor on competing platforms (e.g., Google provides Google Maps not only on its own Android platform but also on Apple iOS).

Extant work suggests that multihoming reduces platform differentiation (Landsman & Stremersch, 2011). This in turn may influence a focal platform's dominant position in the market and thus highly affects platform competition (Cennamo et al., 2018; Cennamo & Santalo, 2013).

Multihoming may induce significant costs for managing and maintaining multiple platform affiliations. For example, complementors are confronted with considerable efforts for developing on multiple platform technologies due to differing architectural specificities and development processes (Anderson et al., 2014; Cennamo et al., 2018). The decision of complementors on digital platforms to multihome is influenced by the proportion of expected benefits and related costs (Bresnahan et al., 2015; Corts & Lederman, 2009), by considerations regarding market or product development (Cenamor, 2021), and complementors' competitive strategy (Tiwana, 2013).

Extant studies highlighted considerable quality trade-offs related to multihoming complements that originate from heterogeneous platform architectures (Anderson et al., 2014; Cennamo et al., 2018; Zhu & Iansiti, 2012). While research provides initial evidence related to implications and consequences of multihoming for complementors, consumers and platform owners, it remains silent on the influence of multihoming on complementors' innovativeness. This is unfortunate, given that multihoming grants complementors access to a potentially immense source of user feedback through increased market reach that is likely to translate into innovation opportunities that address customer requirements (Sahni, 2016).

2.3 User involvement in software innovation processes

User involvement plays an important role in today's product innovation processes (Bosch-Sijtsema & Bosch, 2015). Especially in software development, agile software development paradigms claim for short feedback cycles with users so that they are actively integrated in the development process (Bosch-Sijtsema & Bosch, 2015). Existing innovation management research distinguishes customer involvement between a view of "customer involvement as a source of information" which is requested by the developer and "customer involvement as co-developers" (Cui & Wu, 2017, p. 61). User feedback in mobile platform markets differs from these categories of user involvement, as in contrast to this traditional view, user feedback on these markets is not specifically requested by complementors but posted by the users deliberately to freely chosen topics.

2.4 Leveraging user reviews for software evolution in platform markets

A user review on a platform market is an informal and unstructured piece of text often associated with a rating scheme (Palomba et al., 2015). Existing research on software-based platforms regard user reviews as a valuable source for software innovation in terms of new feature suggestions and ideas for improvements (Guzman & Maalej, 2014; Iacob & Harrison, 2013; Maalej, Kurtanović, et al., 2016). While prior research has addressed the automated requirements elicitation from platform user reviews (a recent literature synopsis can be found in Lim et al. (2021)), only a few studies have addressed possible links from user reviews to complementors' software releases (Noei et al., 2021).

Prior research has studied the effect of reviews on rating optimization: Noei et al. (2021) conducted a study to identify key features for several platform market categories that should be incorporated by complementors in their next update releases in order to receive higher star-ratings. Villarroel et al. (2016) developed a technical prototype for update planning that automatically derived features from reviews to be implemented based on numerical rating metrics.

Further, another related research stream links user reviews to source code. Employing a review mining approach proposed by Chen et al. (2014), the authors discovered that, on average, 49 percent of informative reviews in their dataset containing functional requirements, non-functional requirements or bug reports could be linked to an issue or a commit of source code from a recent software release. Palomba et al. (2015) developed an approach for linking user reviews to source code changes on Android. Furthermore, in a later study, they proposed an approach for extracting useful feedback from reviews to recommend complementors corresponding changes to their software artifacts (Palomba et al., 2017). However, while those initial studies presented first results regarding the impact of user feedback on software development, there is a gap in the literature how user feedback affects complementary innovation within and across platform ecosystems.

2.5 Measuring innovation in the context of mobile software

In this study and in the context of software-based platform ecosystems, we define innovation as a complementor's decision "to release a major update […] in terms of adding new features or functionalities" (Foerderer et al., 2018, p. 445).

To evaluate the innovativeness of functional feature improvements, several metrics have been discussed in the literature (Edison et al., 2013). Beside metrics that aim to measure the quality of an innovation (Edison et al., 2013), we use a count-based metric since we aim to count the number of suggested feature improvements by users in the update notes. Count-based metrics are one of the most common measures, representing, for example, the number of ideas proposed, the number of ideas financed, or new ideas implemented (Edison et al., 2013). During this research, we will count the number of ideas suggested by users in the update notes to measure the effect of user feedback on new feature releases and feature improvement. This decomposition of the updates into individual features is a metric approach of Foerderer et al. (2018) bringing our innovation metric from an update level to a feature level.

3. Method

3.1 Data collection

The data collection consisted of three sequential steps: First, a dataset of relevant applications from both software-based platform markets (Google Play Store and Apple App Store) was collected. Second, the release notes of the selected applications were retrieved. Third, the user reviews for the timespan of twelve months between April 2020 and March 2021 were collected.

In total, we collected the 600 most popular apps (top 200 free, top 200 paid, and top 200 growing apps) from the Google Play Store and the 1200 most popular apps (400 from the free, 400 from the paid, and 400 from the growing app category) from the Apple App Store. The data included the information about the app names and their corresponding app IDs and developers. After the removal of duplicates, a set of 536 Android and 1091 iOS apps remained. All collected applications were further preprocessed to homogenize the writing of the application names.

Afterwards, we extracted all apps which were available in both app stores in a three-step selection process: First, we mapped all applications with the same app name and app developer name (86 apps). Second, we reduced the mapping criteria to the exact matching of the application name with an additional manual check to ensure similarity (additional 37 apps). Third, the last app mapping criterion was limited to an exact match of the developer's name and at least one of the words of the app name. For the word of the app name, we introduced three conditions: it should (i) be longer than three letters to exclude articles and prepositions; (ii) not be equal to the developer's name and (iii) not contain some manually excluded words, such as 'app,' 'game,' or 'editor.' Afterwards, all potential pairs were manually checked for similarity (as a result additional 87 apps were identified). In total, 210 multihoming applications were retrieved.

For all of these applications, we downloaded the release notes for the three-month observation period between the 1st of January 2021 and the 31th of March 2021. Since the Google Play Store only provides information about the latest update, we extracted the missing update notes from 'apkpure.com'. Afterwards, we removed all applications that had silent update notes or update notes that included only minimal bug fixes. As a result, the number of applications in the sample was reduced to 137. After manually deleting applications with non-English update notes as well as games, 111 apps remained in the sample. We removed the game category from this analysis since existing research (c.f. Guzman & Maalej, 2014) indicated that games "represent a special type of software" (Johann et al., 2017, p. 22) resulting in a different nature of user feedback feature management.

For iOS applications, we used the official website of the Apple App Store. The website provides the history of all app versions and the corresponding update notes. Next, we screened the update notes for new feature implementations or improvements. We identified 17 applications with at least one feature

implementation or improvement. Due to the often very brief description of new features and functionalities in the update notes, we enriched the update notes with additional information from the developer's website or the app description.

Finally, in a last step, we collected the reviews of the selected applications for the period between 1st of April 2020 and 31th of March 2021 from both app stores. All reviews that were not written in English or represented only a set of emojis were removed. We restricted our final sample to applications that had no less than 1,000 English reviews across both app stores, resulting in our final dataset of 10 applications.

3.2 Data Analysis

To study the effect of user feedback on complementary innovation, we identified ideas and wishes suggested by the users in the textual description of the user reviews and matched those suggestions to the released functional feature improvements derived from the update notes.

For the NLP task, we relied on Google's popular pretrained 'word2vec' model (Mikolov et al., 2013) and extended it with the reviews from the final sample to get an individual vocabulary for each app pair of semantically related words. In the process, we prepared the dataset by removing the punctuation of the update notes and the user reviews, removed the stop words using the NLTK library and lemmatized (i.e., bringing all words to their normalized form) both datasets with the 'WordNetLemmatizer' from the same library.

To generate the individual vocabulary, we set a threshold for the similarity level of 0.75 (cosine similarity) based on our empirical observations. For each update note, we created a set of words mentioned in the reviews using the adapted vocabulary. Based on this vocabulary, we searched for user reviews that requested this specific feature implementation or improvement. We assume that if at least one of the user reviews in the sample requested a feature improvement before the corresponding update note was released, this user review could have been the source for the consecutive implementation.

For our analysis we developed a small software tool to facilitate the search for matching user reviews. The analysis tool was implemented in Python and consists of three dropdown lists: name, update note, and words from the update note. First, the name of the app to be analyzed (Android and iOS combined) must be selected. Then, all update notes related to this app are loaded, so that consecutively, an update note can be selected for which related user reviews should be identified. Subsequently, the third dropdown list shows of a set of words related to the selected update note. This list of words is generated from the textual description of the update note and from the respective individual app-specific word2vec set of terms incorporating related words from the reviews (see Figure 1). Moreover, a search with individual words or phrases is possible. As a result, the tool provides a list of all reviews that contain the selected words or phrases which were written before the corresponding update note was released. For convenience when manually matching the suggested reviews, the selected expressions are highlighted in the reviews, and marked whether they belong to the Android or iOS version of the app.

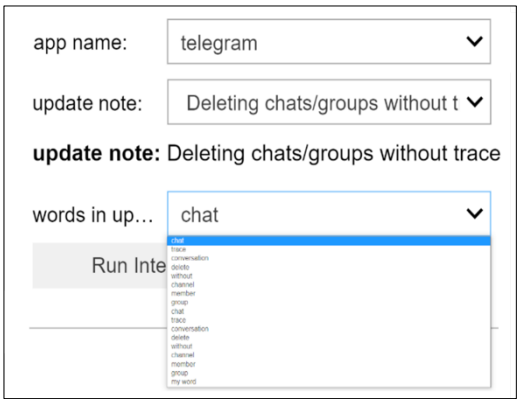

Figure 1. Tool Support

To evaluate the effect of user feedback on complementary innovation within and across both platforms, we calculated the utilization of the users' feedback as a count-based measure:

$$Users'feedback\ utilization\ = \frac{\#\ of\ feature\ updates\ based\ on\ users'suggestions}{Total\ \#\ of\ released\ new\ functional\ features}$$

4. Results

4.1 Descriptive analysis of the retrieved dataset

In total, we identified 120 functional updates in 51 update notes for the selected 10 applications of the final sample within the period between the 1st of January 2021 and the 31th of March 2021 (see Table 1). The update behavior of the different developers proved to be very divers, ranging from updates including only one new feature to up to nine new feature implementations. The update behavior also differed across platforms. During the three-month observation period, 50 features were released for the Android applications and 70 features for the corresponding iOS applications. Table 1 provides an overview over all update notes that were considered in this study.

Table 1. Apps and update notes dates including the number of released new features in brackets

App name	iOS release notes	Android release notes
Zoom	2021-01-12 (1) 2021-02-06 (7) 2021-03-01 (2) 2021-03-25 (9)	2021-01-18 (1) 2021-03-29 (7)
Microsoft Teams	2021-01-22 (3) 2021-02-18 (1) 2021-03-17 (1)	2021-01-09 (1) 2021-01-29 (2) 2021-03-01 (1)
Reddit	2021-02-17 (2) 2021-03-08 (1)	2021-02-10 (1) 2021-03-23 (1)
WW Weight Watchers	2021-01-25 (1) 2021-02-03 (1) 2021-02-19 (3) 2021-03-19 (1)	2021-01-07 (1) 2021-02-08 (1) 2021-03-07 (2) 2021-03-18 (2)
SHEIN-Fashion Shopping	2021-02-08 (1) 2021-03-15 (1)	2021-01-30 (2) 2021-02-08 (1) 2021-03-11 (1)
Telegram	2021-01-28 (6) 2021-02-26 (6) 2021-03-19 (8)	2021-01-28 (5) 2021-02-26 (5) 2021-03-19 (7)
PicsArt Photo & Video Editor	2021-02-11 (1) 2021-03-01 (3) 2021-03-29 (1)	2021-02-11 (1) 2021-03-15 (1)
Blinkist: 15min Book Insights	2021-03-09 (1) 2021-03-22 (1)	2021-02-01 (1) 2021-03-18 (2)
Canva: Graphic Design & Video	2021-02-24 (1) 2021-03-28 (1)	2021-02-25 (1)
eBay	2021-02-22 (5) 2021-03-08 (1)	2021-02-22 (2) 2021-03-09 (1)

Table 2. Amount of collected reviews

App name	iOS	Android	Total
Zoom	3,329	52,309	55,638
MS Teams	2,419	48,994	51,413
Reddit	2,790	26,297	29,087
WW	16,603	2,296	18,899
SHEIN	6,699	17,568	24,267
Telegram	2,394	55,831	58,225
PicsArt	2,640	23,156	25,796
Blinkist	219	825	1,044
Canva	1,231	24,904	26,135
eBay	4,025	31,955	35,980
Total	42,349	284,135	326,484

We collected 326,484 English reviews from both platforms for the selected applications in the final sample. For all applications (except the 'Weight Watchers' app), the number of reviews for the Android version exceeded the number of reviews for the iOS version of the application. This is most likely explained by the larger user base of the Android platform compared to the Apple's iOS platform. Moreover, the number of reviews varied between the different applications. Table 2 depicts the composition of the dataset showing the number of reviews for the two platforms and the 10 applications of the final sample.

4.2 Measuring user feedback utilization on the same platform

To measure the user feedback utilization on each platform, we mapped the content of the user reviews to the update notes of the released feature improvements for each platform, respectively. As described above, we used the analysis tool presented in Chapter 3.2 and carefully examined every application and their corresponding update notes to manually match the user reviews to the feature improvements.

As the result of our analysis, we find that out of the 50 released features in the Google Play Store, 24 (48%) were previously demanded by users in the form of user feedback. On the Apple App Store, out of the 70 released features, 37 (53%) were based on user feedback in the three-month observation period.

Our results could be a first indication that user feedback on the iOS platform is more likely to be incorporated in new feature improvements compared to Android user feedback.

4.3 Measuring user feedback utilization across platform boundaries

In a second evaluation, we conducted a cross-platform analysis. To evaluate how user feedback for multihomed applications stimulates cross-platform innovation, we analyzed how iOS user feedback translated into feature improvements on the Android platform and vice versa. We interpreted a feature improvement as cross-platform innovation if one or more user reviews on one platform resulted in a functional feature improvement on the other.

For the analysis, we reused our analysis tool (see Chapter 3.2). This time, we limited the update notes to those that announce new feature improvements which were implemented on both platforms. After examining the related user reviews, we identified several cases were users mentioned feature ideas only on one platform. Android user feedback was the origin for 10% of the new feature improvements in the Apple App Store, whereas iOS user reviews inspired 8% of feature improvements in the Google Play Store.

4.4 Summary of user feedback utilization

In total, if we merge the iOS and Android feature update notes and aggregate similar proposed feature

improvements from both platforms, we end up with 83 unique features released on the iOS and Android platform for the 10 applications over the three-month observation period. Out of all unique released features, 51 were previously demanded by users in the form of user feedback. Hence, 61% of all feature improvements of our selected multihoming applications were derived from user feedback. Our results highlight the importance of user feedback for the innovativeness of complementors and application quality in platform ecosystems.

5. Discussion

The aim of this paper is to analyze the influence of user feedback in terms of feature suggestions on the functional updates of multihoming applications released on the Apple iOS and Google Android platform. We conducted a quantitative NLP based case study with 10 multihoming complements leveraging 326,484 user reviews. We highlight three main findings.

As a first result, we find that about 61% of the unique functional feature improvements across both platforms in the analyzed time-period were previously demanded by users in the form of user feedback. Out of 83 unique features or functions released on the iOS and Android platform, 51 feature releases emerged from user feedback across the platforms. This finding corroborates our initial assumption that user feedback is an important source for feature improvements across both platforms.

Second, our analysis provides initial indications that user feedback of iOS users is more likely to be incorporated in feature releases compared to feedback from Android users. About 53 percent of the released features on the iOS platform descend from iOS user reviews on the same platform whereas feedback from Android users is the origin of only 48 percent of functional feature releases on the Android platform. Prior research suggests that this observation may be explained by differences in platform governance (e.g., Sørensen et al., 2015). Apple traditionally employs stricter quality screening for new app and update releases compared to Google to ensure high application quality (cf. Comino et al., 2019), pushing complementors to constantly improve their products according to users' needs. Following strict guidelines and screening procedures, Apple limits the access of low-quality applications to the market as well as for updates that are not thoroughly tested (cf. Comino et al., 2019). Zhou et al. (2015) revealed that bugs of multihoming applications are fixed three times faster on iOS compared to Android. This might also reduce the timespan in which users are discussing faulty features and functions in reviews so that they focus more on feature improvements. In contrast, Google conducts less quality screening on their platform leading to less new functional feature updates (McIlroy et al., 2016).

Finally, we observe that about 10% of feature releases were previously demanded in cross-platform feedback. More specifically, about 10% of iOS functional feature releases in our sample were previously demanded in Android user feedback whereas about 8% of Android updates emerged from iOS user reviews. Thus, from a complementor perspective, following a multihoming strategy not only increases the possibility to gain access to a larger market (Rochet & Tirole, 2003) or to reduce the complementors' dependency from a specific platform owner (Halckenhaeusser et al., 2020; Hyrynsalmi et al., 2016), but also acts as a driver of innovation. Finally, this study adds to the extant body of knowledge studying multihoming (e.g., Bhargava et al., 2013), as we report initial evidence that user feedback from multihoming applications might stimulate cross-platform innovation and enhance the applications' quality and innovativeness. Hence, from the perspective of innovativeness and application quality, multihoming might be beneficial for platform owners.

This study offers three theoretical contributions. First, this study contributes to research on user reviews. This study is, to the best of our knowledge, the first to analyze the effect of user feedback on complementary innovation in terms of functional feature updates within and across multiple platform ecosystems. While a large literature stream proposed technical ideas to identify feature requests in app store reviews (e.g., Genc-Nayebi & Abran, 2017; Jha & Mahmoud, 2018; Maalej, Kurtanović, et al., 2016; Scalabrino et al., 2017), the impact of such user reviews on application development has not yet been thoroughly explored. We add to this research gap and the understanding of how user feedback translates into functional feature improvements. We observe that about 61% of the unique functional feature improvements across both platforms were previously demanded by users in the form of user feedback making user feedback a powerful source for feature improvements across platforms. Our approach on how to semantically compare user reviews with update notes may help future research in further analyzing the impact of user feedback on innovation and app quality.

Second, we advance the research discourse on platform governance (Parker et al., 2017; Tiwana, 2015). In particular, we advance our understanding on how differences in platform owner's governance approaches in terms of quality control may lead to different levels of user feedback incorporation and hence, different levels of complementor innovativeness. Our findings suggest that stricter quality screening of

new application and update releases may result in higher levels of user feedback incorporation. By identifying differences in user feedback incorporation, we provide initial evidence that stricter platform governance regarding application quality results in more user-centric complementary innovation. This suggestion opens promising avenues to future research on the influence of different governance regimes on complementary innovation (Young Kang & Suarez, 2022).

Finally, this study adds to the extant body of knowledge studying multihoming (e.g., Bhargava et al., 2013; Cennamo et al., 2018). So far, prior research generally interprets multihoming as undesirable complementor behavior from the perspective of the platform owner (L. Chen et al., 2022; Tiwana, 2013). In particular, research has argued that multihoming reduces the platform's differentiation and competitive advantage over competing rivals in inter-platform competition (Cennamo et al., 2018; Landsman & Stremersch, 2011; Zhu & Iansiti, 2012). However, our results provide initial evidence that multihoming might stimulate complementary innovation and enhance the applications' quality and innovativeness through cross-platform user feedback spillover. In this way, our study adds to the discussion on the management of platform dynamics as it contrasts the traditional perception of platform owners on the detrimental consequences of multihoming (Li & Zhu, 2021). Instead, we find that user feedback from multihoming applications might stimulate cross-platform innovation. Hence, multihoming might have beneficial outcomes for platform owners (Ghazawneh & Henfridsson, 2013).

Further, our results have managerial implications for platform owners as well as complementors. First, our study provides valuable insights for platform owners that perceive multihoming as undesirable complementor behavior. While as such, multihoming might reduce the focal platforms' differentiation in inter-platform competition, our results show that multihoming has potentially unexpected positive impacts on cross-platform innovation. Platform owners should carefully evaluate whether the negative consequences of multihoming (e.g., less diversification in cross-platform competition) outweigh the potentially positive consequences on complementors' innovativeness. Therefore, platform characteristics, potential positive innovation consequences as well as possible negative effects of multihoming should be taken into consideration before making a complex governance decision to facilitate or inhibit multihoming. Further, our results suggest that stricter quality screening might lead to a higher cross-platform innovation rate, reducing the potential negative effects of multihoming. Second, our results may inform complementors. As constant updating and new functional feature releases in line with the users' needs are essential for successful applications, our results show that user feedback can be a powerful source for feedback, requirements identification and hence, innovation. Our results suggest that complementors should be encouraged to not only rely on user feedback within platforms but also to consider feedback from multihomed applications across platforms. Hence, multihoming becomes a viable strategy to not only increase the complementor's market reach and strategic platform diversification but also as a source for innovation in the form of user feedback.

As with any study, our research has limitations that should be addressed. First, since our sample is limited to three months as well as 10 applications, future research might consider extending the observation period and the number of applications to increase the amount of available data. This would help to establish a basis for a more in-depth statistical analysis. Further, future research might study the effect of user feedback on the innovativeness of single-homing applications. Besides, the developed counts-based measurement approach can be enhanced by differentiating between types of feature updates (minor vs. major) and enriched by incorporating changes in ranking of the applications or the users' star rating over time. By including the reaction of users to functional feature releases after the implementation of a suggested feature, future research could further deepen our understanding on how the incorporation of user feedback in complementary innovation affects (perceived) application quality.

6. Conclusion

We investigated the effect of user feedback on complementary innovation of multihomed applications within and across platforms. In a quantitative NLP based case study, we found initial evidence that user feedback is a valuable source for functional feature improvements in complementary markets. We reported three findings. First, we find that 61% of the unique functional feature improvements across both platforms were previously demanded by users in the form of user feedback. Second, we demonstrate that within platform innovativeness is higher for platforms that employ stricter quality control measures for functional feature releases. Finally, we identify that cross-platform user feedback spillover is responsible for about 10% of feature releases providing initial evidence that user feedback from multihoming applications might stimulate cross-platform innovation and enhance the applications' quality and innovativeness.

7. References

Anderson, E. G., Parker, G. G., & Tan, B. (2014). Platform performance investment in the presence of network externalities. *Information Systems Research*, *25*(1), 152–172.

Armstrong, M. (2006). Competition in two-sided markets. *The RAND Journal of Economics*, *37*(3), 668–691.

Armstrong, M., & Wright, J. (2007). Two-sided markets, competitive bottlenecks and exclusive contracts. *Economic Theory*, *32*(2), 353–380.

Bhargava, H. K., Kim, B. C., & Sun, D. (2013). Commercialization of platform technologies: Launch timing and versioning strategy. *Production and Operations Management*, *22*(6), 1374–1388.

Bosch-Sijtsema, P., & Bosch, J. (2015). User Involvement throughout the Innovation Process in High-Tech Industries. *Journal of Product Innovation Management*, *32*(5), 793–807.

Bresnahan, T., Orsini, J., & Yin, P.-L. (2015). Demand heterogeneity, inframarginal multihoming, and platform market stability: Mobile apps. *Proc. 9th IDEI-TSE-IAST Conf. Econ. Intellectual Property, Softw. Internet*.

Caillaud, B., & Jullien, B. (2003). Chicken & egg: Competition among intermediation service providers. *RAND Journal of Economics*, 309–328.

Cenamor, J. (2021). Complementor competitive advantage: A framework for strategic decisions. *Journal of Business Research*, *122*, 335–343.

Cennamo, C. (2021). Competing in digital markets: A platform-based perspective. *Academy of Management Perspectives*, *35*(2), 265–291.

Cennamo, C., Ozalp, H., & Kretschmer, T. (2018). Platform architecture and quality trade-offs of multihoming complements. *Information Systems Research*, *29*(2), 461–478.

Cennamo, C., & Santalo, J. (2013). Platform competition: Strategic trade-offs in platform markets. *Strategic Management Journal*, *34*(11), 1331–1350.

Chen, L., Yi, J., Li, S., & Tong, T. W. (2022). Platform governance design in platform ecosystems: Implications for complementors' multihoming decision. *Journal of Management*, *48*(3), 630–656.

Chen, N., Lin, J., Hoi, S. C. H., Xiao, X., & Zhang, B. (2014). AR-miner: Mining informative reviews for developers from mobile app marketplace. *Proceedings - International Conference on Software Engineering*, 767–778.

Comino, S., Manenti, F. M., & Mariuzzo, F. (2019). Updates management in mobile applications: iTunes versus Google Play. *Journal of Economics & Management Strategy*, *28*(3), 392–419.

Constantinides, P., Henfridsson, O., & Parker, G. G. (2018). Introduction—platforms and infrastructures in the digital age. *Information Systems Research*, *29*(2), 381–400.

Corts, K. S., & Lederman, M. (2009). Software exclusivity and the scope of indirect network effects in the US home video game market. *International Journal of Industrial Organization*, *27*(2), 121–136.

Cui, A. S., & Wu, F. (2017). The Impact of Customer Involvement on New Product Development: Contingent and Substitutive Effects. *Journal of Product Innovation Management*, *34*(1), 60–80.

Cusumano, M. A., Gawer, A., & Yoffie, D. B. (2019). *The business of platforms: Strategy in the age of digital competition, innovation, and power*. Harper Business New York.

Cutolo, D., & Kenney, M. (2021). Platform-dependent entrepreneurs: Power asymmetries, risks, and strategies in the platform economy. *Academy of Management Perspectives*, *35*(4), 584–605.

Edison, H., Bin Ali, N., & Torkar, R. (2013). Towards innovation measurement in the software industry. *Journal of Systems and Software*, *86*(5), 1390–1407.

Eisenmann, T., Parker, G., & Van Alstyne, M. (2009). Opening platforms: how, when and why? *Platforms, Markets and Innovation*, *6*, 131–162.

Eisenmann, T., Parker, G., & Van Alstyne, M. (2011). Platform envelopment. *Strategic Management Journal*, *32*(12), 1270–1285.

Eisenmann, T., Parker, G., & Van Alstyne, M. W. (2006). Strategies for two-sided markets. *Harvard Business Review*, *84*(10), 92.

Foerderer, J., Kude, T., Mithas, S., & Heinzl, A. (2018). Does platform owner's entry crowd out innovation? Evidence from Google photos. *Information Systems Research*, *29*(2), 444–460.

Gawer, A. (2014). Bridging differing perspectives on technological platforms: Toward an integrative framework. *Research Policy*, *43*(7), 1239–1249.

Gawer, A., & Cusumano, M. A. (2002). *Platform leadership: How Intel, Microsoft, and Cisco drive industry innovation* (Vol. 5). Harvard Business School Press Boston.

Genc-Nayebi, N., & Abran, A. (2017). A systematic literature review: Opinion mining studies from mobile app store user reviews. *Journal of Systems and Software*, *125*, 207–219.

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

Guzman, E., & Maalej, W. (2014). How do users like this feature? A fine grained sentiment analysis of App reviews. *2014 IEEE 22nd International Requirements Engineering Conference, RE 2014 - Proceedings*, 153–162.

Hagiu, A., & Lee, R. S. (2011). Exclusivity and control. *Journal of Economics & Management Strategy*, *20*(3), 679–708.

Halckenhaeusser, A., Foerderer, J., & Heinzl, A. (2020). Wolf in a Sheep's Clothing: When Do Complementors Face Competition With Platform Owners? *41th International Conference on Information Systems*.

Hoffmann, P., Mateja, D. N., Spohrer, K., & Heinzl, A. (2020). Socio-Behavioral Elements in Data-Driven Requirements Engineering : The Case of Enterprise Cloud Software. *ECIS 2020 Research Papers*, 172.

Hyrynsalmi, S., Suominen, A., & Mäntymäki, M. (2016). The influence of developer multi-homing on competition

between software ecosystems. *Journal of Systems and Software*, *111*, 119–127.

Iacob, C., & Harrison, R. (2013). Retrieving and analyzing mobile apps feature requests from online reviews. *IEEE International Working Conference on Mining Software Repositories*, 41–44.

Jeitschko, T. D., & Tremblay, M. J. (2020). Platform competition with endogenous homing. *International Economic Review*, *61*(3), 1281–1305.

Jha, N., & Mahmoud, A. (2018). Using frame semantics for classifying and summarizing application store reviews. In *Empirical Software Engineerin*g, 23(6), 3734-3767.

Johann, T., Stanik, C., Alizadeh, A. M. B., & Maalej, W. (2017). SAFE: A Simple Approach for Feature Extraction from App Descriptions and App Reviews. *Proceedings - 2017 IEEE 25th International Requirements Engineering Conference, RE 2017*, 21–30.

Katz, M. L., & Shapiro, C. (1994). Systems competition and network effects. *Journal of Economic Perspectives*, *8*(2), 93–115.

Landsman, V., & Stremersch, S. (2011). Multihoming in two-sided markets: An empirical inquiry in the video game console industry. *Journal of Marketing*, *75*(6), 39–54.

Li, H., & Zhu, F. (2021). Information transparency, multihoming, and platform competition: A natural experiment in the daily deals market. *Management Science*, *67*(7), 4384–4407.

Lim, S., Henriksson, A., & Zdravkovic, J. (2021). Data-Driven Requirements Elicitation: A Systematic Literature Review. *SN Computer Science*, *2*(1), 1–35.

Maalej, W., Kurtanović, Z., Nabil, H., & Stanik, C. (2016). On the automatic classification of app reviews. *Requirements Engineering*, *21*(3), 311–331.

Maalej, W., Nayebi, M., Johann, T., & Ruhe, G. (2016). Toward Data-Driven Requirements Engineering. *IEEE Software*, *33*(1), 48–54.

Martin, W., Sarro, F., Jia, Y., Zhang, Y., & Harman, M. (2017). A survey of app store analysis for software engineering. *IEEE Transactions on Software Engineering*, *43*(9), 817–847.

McIlroy, S., Ali, N., & Hassan, A. E. (2016). Fresh apps: an empirical study of frequently-updated mobile apps in the Google play store. *Empirical Software Engineering*, *21*(3), 1346–1370.

McIntyre, D., Srinivasan, A., Afuah, A., Gawer, A., & Kretschmer, T. (2021). Multisided platforms as new organizational forms. *Academy of Management Perspectives*, *35*(4), 566–583.

Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2013). Efficient estimation of word representations in vector space. *International Conference on Learning Representations*.

Noei, E., Zhang, F., & Zou, Y. (2021). Too Many User-Reviews! What Should App Developers Look at First? *IEEE Transactions on Software Engineering*, *47*(2), 367–378.

Palomba, F., Linares-Vásquez, M., Bavota, G., Oliveto, R., Di Penta, M., Poshyvanyk, D., & De Lucia, A. (2015). User reviews matter! tracking crowdsourced reviews to support evolution of successful apps. *2015 IEEE International Conference on Software Maintenance and Evolution (ICSME)*, 291–300.

Palomba, F., Salza, P., Ciurumelea, A., Panichella, S., Gall, H., Ferrucci, F., & De Lucia, A. (2017). Recommending and Localizing Change Requests for Mobile Apps Based on User Reviews. *Proceedings - 2017 IEEE/ACM 39th International Conference on Software Engineering, ICSE 2017*, 106–117.

Parker, G., Van Alstyne, M., & Jiang, X. (2017). Platform ecosystems: How developers invert the firm. *MIS Quarterly*, *41*(1), 255–266.

Parker, G., & Van Alstyne, M. W. (2005). Two-sided network effects: A theory of information product design. *Management Science*, *51*(10), 1494–1504.

Rochet, J.-C., & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Sahni, N. S. (2016). Advertising spillovers: Evidence from online field experiments and implications for returns on advertising. *Journal of Marketing Research*, *53*(4), 459–478.

Scalabrino, S., Bavota, G., Russo, B., Penta, M. Di, & Oliveto, R. (2017). Listening to the Crowd for the Release Planning of Mobile Apps. *IEEE Transactions on Software Engineering*, *45*(1), 68–86.

Sørensen, C., De Reuver, M., & Basole, R. C. (2015). Mobile platforms and ecosystems. In *Journal of Information technology, 30*(3), 195–197).

Tiwana, A. (2013). *Platform ecosystems: Aligning architecture, governance, and strategy*. Newnes.

Tiwana, A. (2015). Evolutionary competition in platform ecosystems. *Information Systems Research*, *26*(2), 266–281.

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Research commentary—Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, *21*(4), 675–687.

Villarroel, L., Bavota, G., Russo, B., Oliveto, R., & Di Penta, M. (2016). Release planning of mobile apps based on user reviews. *Proceedings - International Conference on Software Engineering*, *14-22-May*, 14–24.

Wang, P. (2021). Connecting the parts with the whole: Toward an information ecology theory of digital innovation ecosystems. *MIS Quarterly*, *45*(1).

Young Kang, H., & Suarez, F. F. (2022). Platform Owner Entry Into Complementor Spaces Under Different Governance Modes. *Journal of Management*, Advance online publication.

Zhou, B., Neamtiu, I., & Gupta, R. (2015). A cross-platform analysis of bugs and bug-fixing in open source projects: Desktop vs. Android vs. iOS. *ACM International Conference Proceeding Series*, *27-29-April*.

Zhu, F., & Iansiti, M. (2012). Entry into platform-based markets. *Strategic Management Journal*, *33*(1), 88–106.