Complementor Embeddedness in Platform Ecosystems: The Case of Google Apps

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Abstract—**Platforms and their marketplaces with complementarities are prominent in the software industry. As the proprietary platform itself exhibits elementary or generic functionality, platform owners depend on a complementor ecosystem populated by third-parties. At present, little is known about mechanisms at play in proprietary ecosystems. Addressing this deficiency, this paper investigates the Google Apps ecosystem through statistical and network analysis. Results show that the Google Apps ecosystem is sparsely connected, the majority of complementors develops one application (83%) and does not have visible relationships (73%). Furthermore, there is a positive relationship between the number of applications a complementor develops and the number of relationships it establishes. The research method and results presented can be used by practitioners as a reference to evaluate their structural position in the ecosystem, while it provides researchers with a quantification of ecosystem characteristics.**

I. Introduction

The rise of platforms in high-technology industries has a profound impact on the increasing interconnectivity between companies. In the software industry, thousands of companies assemble around industry platforms such as iOS, Windows 8 or the PlayStation 3 to develop complementary products, that extend the functionality of the platform [1], [2]. An industry platform herein is defined by Gawer [1] as "a product, service or technology that is developed by one or several firms, that serves as a foundation upon which other firms can build complementary products, services or technologies". The foundation technology exhibits elementary or generic functionality, and provides an extension architecture by means of interfaces (e.g. APIs). Third-parties – from now on to be referred to as complementors – are responsible for the development of complementarities that make the platform appealing to end-users [3]. A platform owner thus depends on an interlinked ecosystem of developers of software products [4], [5], [6].

Platform and ecosystem strategists agree [7], [8], [5] that complementors should be encouraged to establish formal relationships. Relationships such as technological partnerships and alliances drive innovation and collaboration, as increasing interconnectivity fosters the exchange in the ecosystem [7], [8]. Accordingly, platform owners should seek participation of new entrants, stimulating them to develop additional complements. In sum, platform strategies aim to increase the involvement and embeddedness of individual actors in the ecosystem. Embeddedness herein, is the ratio of the number of relationships an actor has with others to the total number of relationships that is theoretically possible [9]. Actors that have many relationships are considered prominent and influential in the ecosystem compared to peripheral peers that only have a relationship with the platform owner to showcase their complements.

While platform strategists are increasingly involved with the development of platform strategies, little is known about their impact on the network structure of proprietary platform ecosystems as longitudinal studies are scarce. Furthermore, ecosystem visualization studies predominantly address open ecosystems due to their relative transparency. To address this deficiency, this paper summarizes the characteristics of the Google Apps ecosystem (a cloud-based office suite) and examines the influence of vendor development activity on their embeddedness in the ecosystem. In order to do so, this paper answers the research question: *"What is the influence of the number of complements developed by an actor on its embeddedness in a proprietary platform ecosystem?"*

This paper presents a visualization and analysis of the Google Apps platform ecosystem by means of social network analysis [9], [10]. The Google Apps ecosystem is visualized based on data collected from its app store (Google Apps Marketplace), and by means of manual reconstruction of formal relationships. Through the analysis of the Google Apps ecosystem, the factors that shape the network structure of platform ecosystems are identified. Furthermore, this paper provides empirical evidence for the recurring hypothesis [7], [8] that there is a relationship between the increasing involvement of an actor in the ecosystem and its emergence to collaborate with other complementors in the same ecosystem. In addition, this paper aims to improve the understanding of mechanisms at play in platform ecosystems, being among the first to visualize the ecosystem that forms around a proprietary platform.

The remainder of this paper continues with an overview of related work in Section II, followed by a description of the research approach in Section III. Section IV presents an overview of the Google Apps ecosystem, containing a network graph of part of the ecosystem. Section V describes the analysis of the Google Apps ecosystem and provides an answer to the research question. In Section VI validity threats are addressed, followed by a conclusion and suggestions for future research in Section VII.

II. Related Work

Software companies engage in alliances and technological partnerships in search for increased interoperability, integration, specialization and influence [11], [8]. Platform owners stimulate this interconnectivity to benefit from network effects such as co-creation and co-innovation by complementors [7],

[1]. Platform owners face complex and far reaching decisions in the management of a platform and its surrounding ecosystem. According to West [12], platform owners face the challenge of balancing appropriability and adoption. This refers to the balance between reaping benefits from a proprietary platform while these benefits are connected to the adoption of the platform by complementors and end users. At the same time, platform owners entice to commit complementors to their platform, for example, through the stimulation of collaboration in the ecosystem [7]. Not only does collaboration foster the diffusion of innovation and productivity in the ecosystem [5], [13], it also provides cohesion in the ecosystem which is pivotal in decision-making about interactions between complements and platform [7], [14].

This paper complements previous work that produced techniques for data extraction from app stores [15], [16], [2], and builds on the body of literature on the visualization of interfirm relationships. Quaadgras [17] and Basole [18], for example, presented results of investigations into the RFID and mobile ecosystems. Basole [18] used centrality and network density metrics [9] to calibrate the ecosystem. The author found that emerging segments in the mobile industry were sparsely connected compared to their more mature counterparts.

Iyer, Lee and Venkatraman [11], visualized the proprietary ecosystems of IBM, Microsoft and SAP between 1990 and 2002. The ecosystems can be visualized as a hub-and-spoke network in which the platform owner is the hub in the center. The platform owner is surrounded by complementors that engage in formal and competitive relationships with the platform owner and each other, providing a coopetitive environment [19]. Between 1990 and 2002, the ecosystems witnessed a stable growth, yet became more sparsely connected as companies were found selective in their partnership activities.

III. Research Approach

The complementors, the formal relationships among them and the characteristics of the Google Apps ecosystem are analyzed by means of a single case study [20]. Google Apps is a cloud based office suite platform, intended for use by enterprises and governmental or educational institutions. The platform consists of scalable versions of Google products, such as Gmail, Google Drive and Google Sites. Apart from its standard functionality, Google Apps depends on complementors that diversify or extend its functionality. The complements – either developed by Google or third-parties – can be found in the Google Apps Marketplace[1]. Only the complements listed under the category *"products"* were considered, meaning that service providers have been excluded.

The Google Apps Marketplace holds application specific metadata for each complement, which among others includes information about the developer, pricing model, certification status, partner information, and reviews. As this metadata is available on a dedicated website, it could be retrieved by means of a web crawler. The crawler used leans on the architecture of a previous initiative by Burkard, Draisbach, Widjaja and Buxmann [15], who in 2010 retrieved application specific metadata from five app stores on a weekly basis. The crawler is Java-based and has a two layer architecture. The universal layer is responsible for all data handling. The second layer provides data retrieval from the marketplace. On *12-02-2013*, all application specific metadata for the Google Apps Marketplace was retrieved in two stages. First, the crawler traversed the entire list of complements in the Google Apps Marketplace over multiple iterations to the point at which no new applications were found. Second, all application specific metadata could be read-in through their respective URLs. The web pages were converted into Document-Object-Models with an open-source tool called NekoHTML[2], as this simplified the parsing of data. Afterwards, all data was stored in a central case study MySQL database in accordance with predefined pattern templates [20].

Contrary to the application specific metadata, the formal relationships between complementors could not be retrieved automatically. However, business and competitive relationships could be retrieved from company websites, partner portals, company news feeds, and proprietary or openly accessible databases [18], [11]. The relationships that can be established within the boundaries of a platform ecosystem are shown in the meta-model in Fig. 1. All complementors were identified by means of an SQL query on the database with vendor data, followed by manual verification because some companies use multiple aliases. Both aliases *'Google Inc.'* and *'Google Labs'*, for example, refer to Google. The company website of each vendor was then visited to identify the partnerships they maintain with other complementors. In addition, CrunchBase[3] was queried to identify competitors and additional partnering relationships. Herein, relationships are regarded as undirected, meaning that if NetSuite lists a relationship with Box, Box is also considered to have a relationship with NetSuite, even if Box omitted to list NetSuite as a partner.

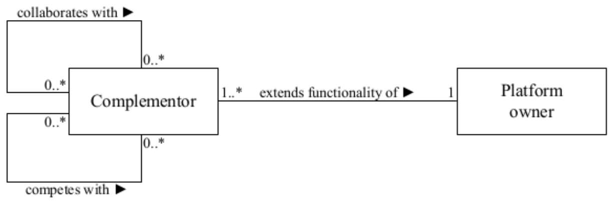

Fig. 1. Meta-model of relationships in a proprietary platform ecosystem

The identified relationships were maintained in an adjacency matrix, created in UCINET[4]. An adjacency matrix is a matrix in which for every pair of actors (e.g. an adjacency pair), the presence or absence of a relationship is denoted [9]. In the adjacency matrix, **-1** was used to indicate the presence of a competitive relationship, **1** was used to indicate the existence of a partnership, and **0** indicated that two actors do not have a relationship. Because of its compatibility with UCINET, Gephi[5] [21] was used to visualize the ecosystem by means of network graphs. The structural properties of the network were computed with either UCINET or Gephi.

To validate the accuracy of the data collection method and to gain insight into the partnering strategies of Google Apps complementors, 35 vendors were contacted by email.

[1] http://www.google.com/enterprise/marketplace

[2] http://www.nekohtml.sourceforge.net

[3] http://www.crunchbase.com

[4] http://www.analytictech.com/ucinet

[5] http://www.gephi.org

The *eighteen largest vendors* and the *seventeen vendors with the most business relationships* were contacted. The complementors were asked whether their relationship portfolio as identified was complete and whether or not they take an active stance towards partnering with other complementors in the Google Apps ecosystem.

IV. Descriptives of the Google Apps Ecosystem

This section provides a description of the Google Apps ecosystem. The units of analysis of the Google Apps ecosystem are the complementors and the relationships among them. Accordingly, the remainder of this section first elaborates on the distribution of complementors, followed by a description of the network structure of the ecosystem.

A. Complementors

On *12-02-2013*, the Google Apps Marketplace contained *1354* applications, developed by *993* different developers. *Thirteen* applications are developed by Google, using the aliases *Google Inc.* and *Google Labs*. The *992* complementors develop *1341* applications, with contributions varying between *one and fifteen* applications. On average, each actor develops *1.36* complements with a standard deviation of *0.61*. The vast majority (83%) of the ecosystem thus consists of complementors that develop one application. A complete overview of vendor distribution based on the number of applications they develop is shown in Table I. Among the complements are integrations with other platforms, data synchronizations, and extensions that facilitate the execution of business processes.

TABLE I. Distribution of complementors based on the number of applications developed

# of applications	# of complementors
15	1
14	2
11	1
10	1
9	2
8	2
7	4
6	5
5	6
4	10
3	26
2	104
1	826

The ecosystem is connected by *1391* formal relationships such as technological partnerships and alliances. Out of the total number of relationships, *143* competitive relationships were identified, accounting for *10.28%* of all relationships in the ecosystem. This finding supports the notion that ecosystems can be regarded as coopetitive [19] environments, where collaboration and competition occurs simultaneously. Furthermore, the overall network is connected with an average of *1.26* relationships per actor, as every complementor is considered to have a business relationship with Google. To stimulate the engagement of actors in the ecosystem, Google employs a partnership model (i.e. Google Enterprise Partners) that crosses the boundaries of the Google Apps ecosystem. In addition, Google offers certification programs for applications or reseller services. Whether a vendor participates in one of these programs is indicated on the Google Apps Marketplace. Participation in both programs accounts for a mere *7,36% (73 vendors)* of the ecosystem.

B. Ecosystem

The Google Apps ecosystem is constituted of actors (nodes) and the relationships among them (edges). Network metrics [22], [9], [10] were used to calibrate the main structural properties of the network. The values found for these metrics are summarized in Table II (network level metrics) and Table III (node level metrics). In sum, the following metrics are used to calibrate the network structure on the network level:

- **Size:** The number of nodes the ecosystem consists of.
- **Density:** The ratio of relationships that are present to the maximum number of relationships that can theoretically be formed in the ecosystem.
- **Centralization:** The ratio of the structural position of the platform owner to the embeddedness values of all complementors.

TABLE II. Network level metrics for the Google Apps ecosystem

Metric	Value
Size	993
Density	0.00282
Density (noncompetitive)	0.00253
Centralization	0.9994

Following a centralization score of *99,94%* – a measure that compares the network to an ideal star-shaped network in which no complementor relationships exist – Google is found to be the central player responsible for employing the initiatives in the ecosystem. With a network density lower than *1%*, the Google Apps ecosystem has a sparse network structure. The majority of complementors are thus new entrants, limit themselves to the development of their applications, or maintain a selective set of key relationships. Since our study shows an increase of *68%* in the number of complementors compared to the figures found by Burkard et al. [15] in November 2010, the presence of a substantial amount of new entrants is apparent. In addition, part of the small complementors (i.e. that only develop one application) are individuals rather than enterprises.

To provide additional insights related to the role of individual actors in the ecosystem, the following network metrics have been used for node level measurements of which the values are presented in Table III:

- **Embeddedness:** The ratio of the number of relationships an actor has to the number of relationships that is theoretically possible.
- **Eigenvector centrality:** The structural position of an actor as a function of its relationship to other actors, weighted by their centralities.
- **Clustering coefficient:** The ratio of the number of partners of an actor that is also connected to one another to the total number of partners an actor has.

TABLE III. Node level metrics for the Google Apps ecosystem

Metric	Min.	Max.	Avg.	Std. dev.
Embeddedness	0.00101	1	0.00282	0.00285
Embeddedness (noncompetitive)	0.00100	1	0.00253	0.00261
Eigenvector centrality	0.0298	1	0.0318	0.00315
Clustering coefficient	0	1	0.193	0.287

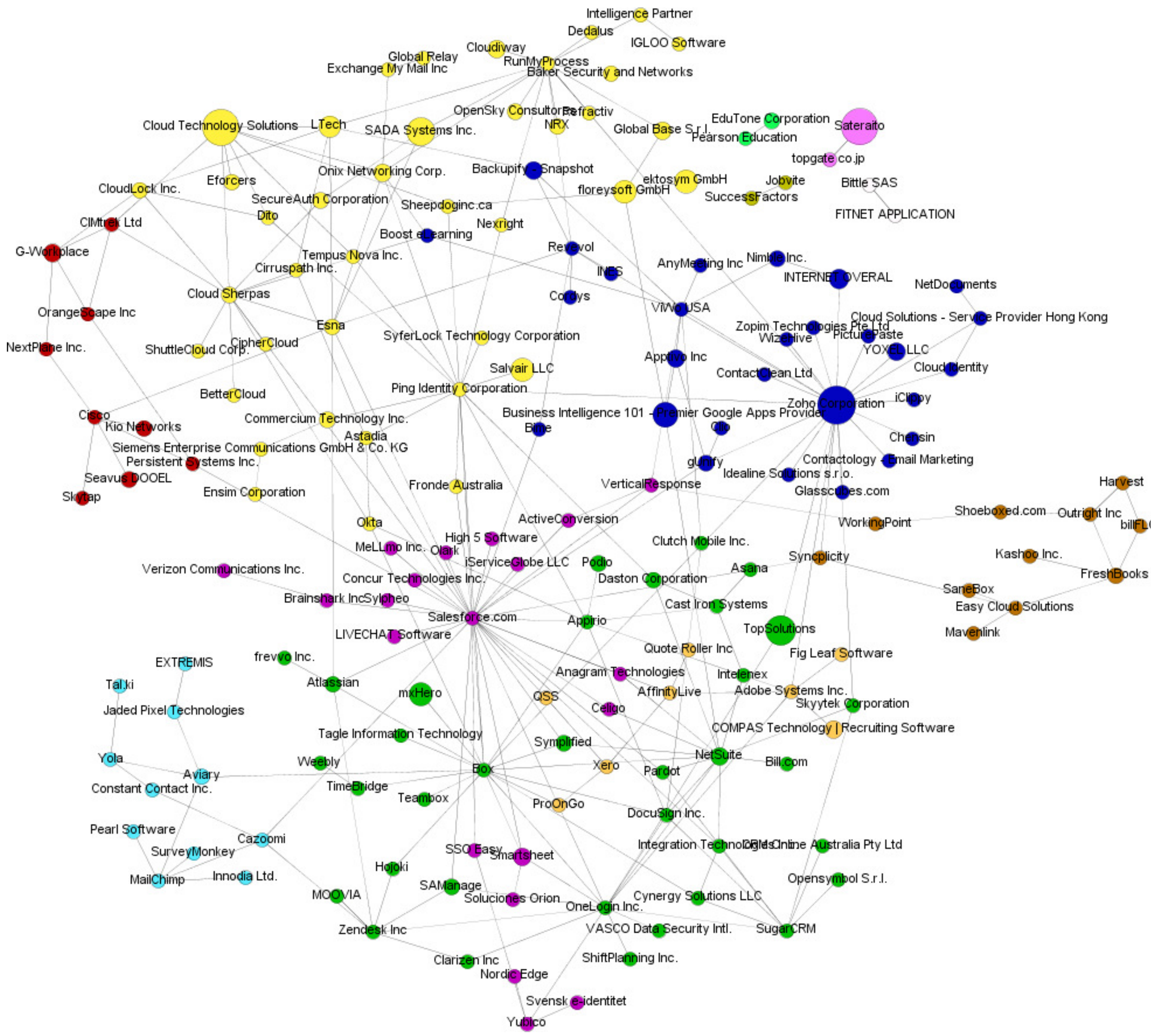

Fig. 2. Network graph showing clusters in the Google Apps ecosystem

The high standard deviation for embeddedness reveals the presence of a small group of influential actors in the ecosystem, while 73% of actors are solely connected to Google. Closer inspection of the dataset confirms this finding, identifying *Salesforce.com* as the most embedded actor with *48* relationships, followed by *Zoho Corporation* with *33* partners, and *Box* that has *21* relationships. Discarding competitive ties, *Salesforce.com* and *Zoho Corporation* lose the most connections, evidencing the presence of competitors. The clustering coefficient reveals the presence of a number of clusters [10] in the ecosystem, being groups of actors that maintain many relationships with each other.

A useful network visualization could be created after 'cleansing' the dataset. First, the remainder of this research excludes competitive relationships. Second, to uncover the topology beneath the hub-and-spoke network, Google has been removed from the visualization. Finally, complementors solely connected to Google have not been included in the graph. The resulting network visualization of the Google Apps ecosystem is shown in Fig. 2. The sizes of the nodes in the graph represent the number of applications they develop for Google Apps.

The ecosystem has been divided in clusters by means of the modularity algorithm in Gephi, which is based on the work by Blondel, Guillaume, Lambiotte and Lefebvre [23]. It distinguishes clusters as groups of actors that are densely connected to one another while sparsely connected to other clusters. In other words, the algorithm searches for sparseness within the overall network. In total, *twelve* clusters were found of which the members are grouped accordingly in Fig. 2. Observable is the difference in cluster sizes. There are four clusters that consist of two complementors interacting with each other, but not with the other actors in the ecosystem. The small clusters consist of companies headquartered in the same country. *Sateraito* and *topgate.co.jp*, for example, are both Japanese whereas *Bittle SAS* and *FITNET APPLICATION* are French. The larger clusters reflect more differences. The *Salesforce.com cluster* for instance has a hub-and-spoke network topology, due to the platform efforts of *Salesforce*. Similarly, companies from different geographic locations are grouped around *Zoho Corporation*, making the clusters of *Salesforce.com* and *Zoho Corporation* examples of technology clusters. Other clusters, such as the one in the upper left corner with *OrangeScape* in the middle, lack one central actor and seem to be merely connected to one another through direct and indirect relationships. Geographic location herein does not seem to be an influential factor, as the *OrangeScape cluster* includes multinationals and companies headquartered in the United States, Canada, Mexico, Sweden and the Netherlands.

Noteworthy is the absence of a couple of large actors in Fig. 2. *SaaSt* for instance at present offers eleven applications for Google Apps, yet they are not connected to any other complementor. Similarly, *myERP* is absent while it has nine applications in the app store. Other large complementors such as *Zoho Corporation* (15 applications), *Cloud Technology Solutions* (14 applications) and *TopSolutuions* (10 applications) are among the most central actors in the ecosystem.

V. Analysis

This section describes the analysis of the Google Apps ecosystem and answers the research question. The remainder of this section distinguishes between a quantitative and qualitative analysis. The quantitative part of the analysis answers the research question based on the descriptives summarized in the preceding section. The qualitative part of the analysis considers the input received from the complementors that were contacted by email. Out of the thirty-five complementors, *ten (29%)* returned an answer. Respondents were equally spread over the two contacted categories, meaning that both well embedded actors as active developers responded, providing a more representative input.

A. Analysis of Quantitative Data

Relationship establishment among complementors makes up a critical part of the success of an ecosystem. Prominent actors in the ecosystem seek to extend their relationship portfolio as it eases access to resources and their means to exert power in the ecosystem [11], [5]. Similarly, small complementors seek partnerships under pressure of increasing specialization and technological integration with existing complements in the ecosystem to benefit from established reputation [5]. Moreover, the platform owner benefits from interconnectivity, since it indicates commitment to the platform [7]. Also, increasing embeddedness of actors increases lock-ins, as connected elements are less likely to depart the ecosystem [7]. Subsequently, the argument is that increasing application development and growing interest in relationship establishment coincide, due to the increased power position of central players [9], [5], [10]. To test this argument, the following hypothesis is formulated:

H1: There is a positive relationship between the number of applications an actor develops and its embeddedness in the ecosystem.

The hypothesis is tested by means of a Pearson correlation analysis. For every complementor, the number of applications they developed were considered as the first variable, and the number of partners (i.e. embeddedness) as the second variable. As shown in the SPSS output fragment in Fig. 3, the two variables significantly correlate *(0.232)*, meaning that complementors that develop more applications engage in more formal relationships and the growth in the two variables thus coincides. The correlation is only significant at the *0.01* level since large complementors such as *SaaSt* and *myERP* have not yet established any relationships. A likely explanation for this comes from one of the respondents, who indicated to *"not have established relationships yet, as the focus of a new entrant lies on the extension of its product portfolio"*. Also, new entrants may have partnerships in before their actual entrance to the ecosystem, which has a mitigating effect on the correlation.

Correlations

		NumberOfApplications	Degree
NumberOfApplications	Pearson Correlation	1	,232**
	Sig. (2-tailed)		,000
	N	992	992
Degree	Pearson Correlation	,232**	1
	Sig. (2-tailed)	,000	
	N	992	992

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 3. SPSS output for correlation between number of applications developed and embeddedness

B. Analysis of Qualitative Data

During the survey among complementors, companies were presented with a description of the Google Apps ecosystem as described in the previous section. When asked, *90%* indicated that the information collected about their company and its relationships is accurate and complete. One respondent indicated to have additional relationships with Google Apps vendors, but omitted to list these engagements on their website. Few respondents indicated to be aware of the network topology of the ecosystem or their own structural position within this network. Most complementors indicated to have an overview of their own relationship portfolio, but lack insight into the dynamics of the network as a whole.

The stance towards relationship management differs among participants in the ecosystem. The majority of respondents indicated to be selective in their partnering activities, limiting themselves to key partnerships. The companies indicated to seek for technological partnerships and integrations with other application vendors to *"complement existing applications"*, evidencing the finding that relationship initiation in the Google Apps ecosystem is driven by technological needs rather than geography. Accordingly, matchmaking among complementors in the ecosystem could prove more effective when the process is based on technological needs. Other vendors, however, indicated to not see any added-value with regard to relationship initiation within the ecosystem, confirming earlier findings of case studies performed with software vendors [24].

VI. Discussion

The results presented in this paper were based on empirical data, obtained by automated and manual data collection from the Google Apps Marketplace. Since the data collection process is labor intensive, to the knowledge of the authors it is the first time a similar approach has been used to visualize the ecosystem around a proprietary platform. Accordingly, a validation was implemented to evaluate the completeness and accuracy of the data collection method. Results of the validation showed that the method was found accurate.

Regardless of the results of the validation step, reservations have to be made with regard to data completeness, due to usage of proprietary sources. For example, some complementors indicated on their website to have technological partners or to employ partnership models, while they omitted to list the companies that constitute their relationship portfolio. To overcome this limitation, CrunchBase was used to identify key relationships that may have been absent on the website.

VII. CONCLUSION

This paper described the network topology of the Google Apps ecosystem. The analysis investigated the influence that the number of applications developed by an actor has on its embeddedness (i.e. its number of partners), as the hypothesis was that increasing development activity coincides with a growing emergence to establish relationships. By means of app store data extraction metadata about vendors was collected. After that, formal relationships (e.g. technological partnerships, alliances) in the ecosystem were manually identified by creating partner lists for every vendor, based on the information available on company websites and CrunchBase.

At present, the ecosystem is populated by 992 complementors that develop 1341 complementary applications for Google Apps. Illustrative for the recent growth of the ecosystem,is the number of vendors that develop one complement (83%). The ecosystem is a sparsely connected network with on average 1.26 relationships per actor, as 73% of the complementors is solely connected to Google. The ecosystem is composed of twelve clusters, of which larger clusters are technology-based while the small clusters were found to consist of geographic partnerships. When asked, complementors indicated to not be aware of the current topology of the Google Apps ecosystem, and to select their partners based on technological complementarity. To provide an answer to the research question, a correlation analysis was performed, returning a significant correlation of 0.232 evidencing a positive relationship between the number of applications developed by a complementor and its need to establish relationships.

This paper provides a step towards better understanding of the mechanisms at play in proprietary platform ecosystems. Longitudinal studies are an important direction for further research, as they provide insight in the evolution of the ecosystem over time, as well as the influence of changing strategies of individual companies on the ecosystem as a whole. As this research focused on software products, more research is needed to identify the role of service providers or system integrators for value creation within the ecosystem. Furthermore, this ongoing research project aims to compare multiple proprietary platform ecosystems, to uncover the factors shaping the network topology of the ecosystem.

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