

SOFTWARE ECOSYSTEMS AND DIGITAL PLATFORMS – A THEORETICAL REVIEW

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Abstract: *Recent literature has focused increasingly on software ecosystems and digital platforms. Digital platforms, as the foundation that supports software ecosystems' development, have reshaped the traditional business models by focusing more on new dimensions such as stakeholders instead of customers and suppliers, or value co-creation instead of value creation. Software ecosystems contribute significantly to how business is conducted around the world. By performing an overview of recent literature published in Web of Science top academic journals, our paper presents a bibliometric co-occurrence and co-authorship analysis of both software ecosystems and digital platforms. The results show that software ecosystems and digital platforms research collide based on the key words co-occurrence analysis under a certain degree, underlying the evolution of the two topics towards platform ecosystem and platform economy research in recent years.*

Keywords: *software ecosystems, SECO, digital platforms.*

JEL Classification: *M15*

1. Introduction

The world of business is changing today as through the pervasiveness of digital technologies driving the technological revolution. We are witnessing the creation of Economy 4.0, characterized by the ubiquity of information, bottom-up participation, “co-creation”, self-organization and collective intelligence as new organizational principles (Helbing, 2021). The trend now includes the creation of various complex, interdependent software solutions in which the multiple stakeholders interact to co-create value within the same ecosystem. These software ecosystems are based on platforms, representing various technologies supporting them. Within software ecosystems, the platform is the key technological resource (Dal Bianco et al., 2014). Whereas traditional firms create value within the boundaries of a company or a supply chain, digital platforms utilize an ecosystem of autonomous agents to co-create value (Hein et al., 2020). Some of the most well-known such platforms, with millions of users around the world, are: Airbnb in hospitality, Uber, Lift, Bolt and BlaBlaCar in transportation, Deliveroo in food delivery, Facebook, Instagram, Whatsapp in communications, Netflix, Youtube, Tiktok in entertainment industry.

Digital platforms are the main drivers of the platform economy, which along with the proliferation of the internet and the widespread diffusion of mobile phones have transformed how consumers engage and share experiences, buy products and food, pay for goods and services, access health care, and share accommodation and resources (Fu et al., 2021). In order to succeed in today's economy, entrepreneurs, consumers and academics alike must grasp the implications of these software ecosystems and digital platforms as they behold tomorrows' successful businesses. Our paper focuses on understanding software ecosystems and digital platforms, by exploring the articles published in Web of Science database. Using the Vos Viewer software, we are able to perform a co-occurrence and co-authorship bibliometric analysis in order to find common ground research of the two topics we investigate, but also a bibliometric analysis of themes, their distribution, and the main clusters. The paper is structured as follows: we cover concepts definitions in a brief literature review, proceeding to research methodologies, results, implication and conclusions.

2. Brief literature review on software ecosystems and digital platforms

A software ecosystem is the interaction of a set of actors on top of a common technological platform that results in a number of software solutions or services (Manikas and Hansen, 2013), that enable, support and automate the activities and transactions by the actors in the associated social or business ecosystem and the organizations that provide these solutions (Bosch, 2009). In this extended group of stakeholder's new products and services are created, improved, adapted, and reshaped to be made available to an end-consumer who is no longer their sole beneficiary, but can in the same time take the role of the contributor and actor in this process. In this ongoing increased stakeholders' interactions and involvement modern, fast products and services are emerging to challenge traditional business models into new forms. The success of software ecosystems highly depends on the variety and quality of end-user applications (Dal Bianco et al., 2014). This approach differs from IT in that the initiating actor does not necessarily own the software produced by contributing actors and does not hire the contributing actors (Manikas and Hansen, 2013).

Digital platforms on the other hand, represent the technologies that support software ecosystems. The digital economy has led to significant socio-economic transformations in all aspects of our society and livelihoods (Fu et al., 2021) and digital platforms contributed by putting labour at the centre of their valorisation and therefore of their business models (Baronian, 2020). Digital platforms build on the widespread availability of constantly evolving information technology, such as cloud computing, in-memory databases, and analytical solutions for big data (Hein et al., 2020). Platforms are products or services that function as foundations upon which others—termed complementors—can build complementary products, services, or technologies (Eckhardt et al., 2018). The emergence of large-scale digital platforms such as Facebook, Google Play and Apple App Store around 2008 has created opportunities for independent entrepreneurs to offer their self-

developed software applications (“apps”) to large groups of platform users (Fan et al., 2021).

From the engineering perspective, the connection between various types of digital platforms and software ecosystems can be explained in very simple and easy to visualize lines. Historically, software ecosystems have evolved from component-based systems to software platforms, to software product lines and became increasingly common for software organizations (Dal Bianco et al., 2014). The product line architecture and shared components, referred to as the platform, if made available to parties external to the company, enables the company to transition from a software product line to a software ecosystem (Bosch, 2009). In the table below we illustrate the various types of digital platforms used for different alternatives of software ecosystems. According to the literature, software ecosystems are an effective way to construct large software systems on top of a software platform by composing components developed by internal and external contributors (Manikas and Hansen, 2013) interacting and co-creating value for the end consumer. In the recent years, the term software ecosystem and digital platform seem to evolve towards a combined form called platform ecosystem (Fan et al., 2021), which is linked to platform economy. The platform ecosystem is based on a digital platform and includes all companies, the organization and other formal elements from the platform environment, which influence the value of the platform and its participants (Drewel et al., 2021). It is an assemblage of the offerings developed on that platform (Kapoor et al., 2021). Whereas, platform economy refers to a situation in the future in which major economic sectors have completed a transformation into a platform ecosystem (Drewel et al., 2021).

Table 1 Software ecosystems and digital platforms

Category/Platform	Desktop	Web	Mobile
End-user programming	MS Excel, Mathematica, VHDL	Yahoo, Pipes, Microsoft Pop Fly, Google mashup editor	-
Application	MS Office	Sales Force, Ebay, Amazon, Ning	-
Operating system	MS Windows, Linux, Apple IOS	Google App Engine, Yahoo developer, Bungee Labs	Android, iPhone

Source: adapted from (Bosch, 2009, p. 2)

3. Research methodology

In this paper we perform a bibliometric analysis employing Vos viewer on software ecosystems and digital platforms literature. We selected Web of Science database, on which we performed a search on software ecosystem and digital platform, using commas and the apteryx symbol in order to include all relevant forms of the 2 expressions. We applied inclusion/exclusion criteria limiting the search to journal

articles and obtained 209 results on software ecosystems and 3323 on digital platforms.

We saved the data bases and performed the bibliometric of co-occurrence analysis on keywords used in research on the selected topics to explore where they overlap. Then we tested for the co-authorship for identifying the most promising authors, contributing with the highest number of papers on the selected topics and their set of relations. Maps with visual representations of the results were generated and are presented in the results section below.

4. Results

A total of 3532 peer-reviewed articles (209 on software ecosystems and 3323 on digital platforms) from top academic journals were identified in WOS data base. The maps of visual representation of the co-occurrence in keywords to observe the overlapping of the two topics can be seen below in Figure 1 and Figure 2. Keywords provided by authors of the papers on software ecosystems occurring for more than 1 time in the WOS core database were enrolled in the final analysis. Of the 218 keywords, 218 met the threshold for software ecosystems, as seen in Figure 1. We chose the minimum number of occurrences at 1 for software ecosystems due to the smaller sample size of articles included.

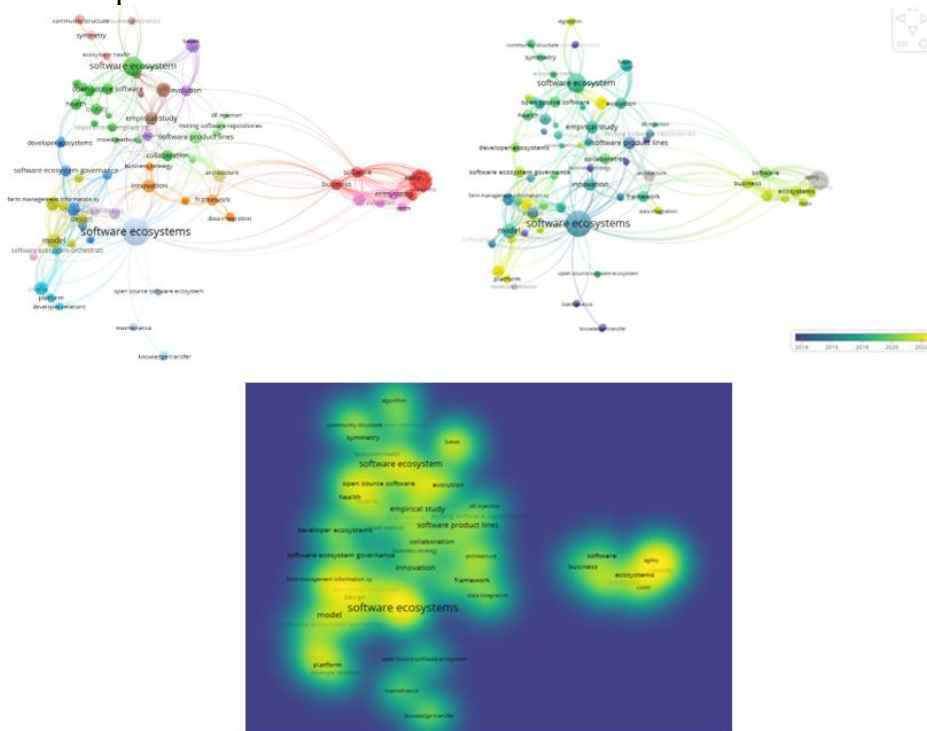


Figure 1 Co-occurrence analysis of software ecosystems

As we can observe in Figure 1, there are some clear clusters of keywords identified in the academic literature. The size of nodes indicates the frequency of occurrence

and curves between the nodes represents their co-occurrence in the same publication. The shorter the distance between two nodes, the larger the number of co-occurrences of the two keywords. The identified clusters revolve around keywords such as innovation, empirical research, open-source innovation, agility and capability, governance, design and model. Considering the evolution in time of the research (top left corner in Figure 1), we note that researchers first focused on the basics of software ecosystems (product lines, maintenance, knowledge transfer, business strategy), and gradually moved towards topics on innovation framework, symmetry, community structure, open-source software. In recent years the academic literature on software ecosystems focuses more on platforms, costs, governance and business aspects such as costs. In the density visualization topics such as software ecosystems, boundary resources, agility, open-source software, evolution, health and platform got mentioned by the highest number of articles.

Figure 2 depicts bibliometric results on digital platforms, including keywords identified in the literature, with an occurrence of at least 5 times, 12.752 results out of which 802 met the threshold. We can observe a number of research clusters, such as the one in green on social media topics, in yellow on labor and platform work, in blue on technology and innovation, in red on health. In the top left corner of Figure 2 a recent evolution of research topics can be observed based on keywords revolving around social media in 2019, moving towards innovation in early 2020, and later focusing on Covid-19 and health in 2022. In the density visualization digital platforms, technology, innovation, social media, and covid-19 are the topics that generated the highest number of publications.

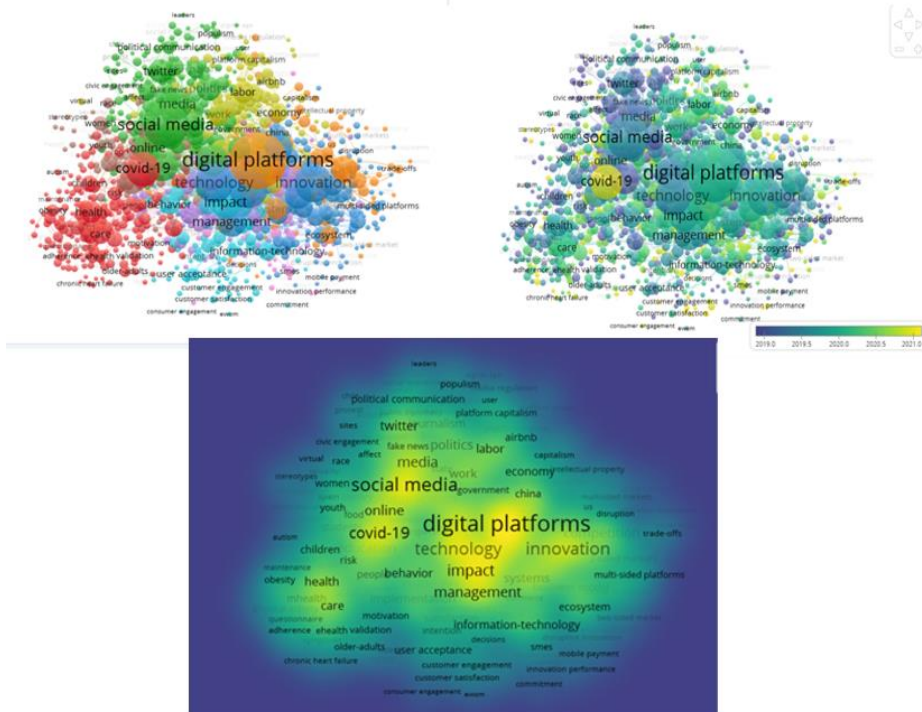


Figure 1 Co-occurrence analysis of digital platforms

In recent year the term software ecosystem and digital platform have emerged in a new term, which is platform ecosystem (Fan et al., 2021).

In Table 1 we grouped the results on the co-authorship analysis on the analysed topics, including only the top 30 authors resulted in the Vos Viewer on both topics based on an occurrence of at least 3 times.

Table 1 Co-authors analysis results on software ecosystems and digital platforms

	Software ecosystems			Digital products		
	Authors	docs	total link strength	Authors	docs	total link strength
1	LIAO, ZF	5	27	ALI, L	5	24
2	ZHANG, Y	5	27	EKMAN, I	5	24
3	LIU, SZ	4	23	FORS, A	5	24
4	LIU, H	2	11	BARENFELD, E	4	20
5	ZHOU, Y	2	10	WALLSTROM, S	4	20
6	BERGER, T	2	9	GYLLENSTEN, H	3	16
7	BLINCOE, K	2	8	SWEDBERG, K	3	16
8	DAMIAN, D	2	8	ANEMA, JR	3	15
9	JANSEN, S	5	8	BOOT, CRL	3	15
10	ROBBES, R	2	8	BROUWERS, EPM	3	15
11	HE, DY	1	7	HAVERMANS, BM	3	15
12	JIN, HZ	1	7	HOUTMAN, ILD	3	15
13	WU, JS	1	7	KRCMAR, H	6	15
14	YANG, L	1	7	VAN DER BEEK, AJ	3	15
15	ZHAO, BH	1	7	LIAO, ZF	5	13
16	CZARNECKI, K	1	6	ZHANG, Y	5	13
17	DIENST, S	1	6	ARDEN, MA	3	12
18	PFEIFFER, RH	1	6	DRABBLE, SJ	3	12
19	SHE, S	1	6	HUTCHINGS, M	3	12
20	TARTLER, R	1	6	MAGUIRE, C	3	12
21	WANG, Y	1	6	O'CATHAIN, A	3	12
22	WASOWSKI, A	1	6	SCHREIECK, M	4	12
23	WIESE, I	2	6	TRABUCCHI, D	8	12
24	YI, MJ	1	6	WIESCHE, M	4	12
25	ANQUETIL, N	1	5	HEIN, A	4	11
26	BEULENS, AJM	1	5	LIU, SZ	4	11
27	BOSCH, J	4	5	BOHM, M	3	10
28	BRAGA, R	1	5	BUGANZA, T	6	10
29	BRINKEMPER, S	2	5	HUNTINGTON, P	5	9
30	CAMPOS, F	1	5	MULLER, JM	4	9

5. Conclusions

Software ecosystems and digital platforms represent two topics with much in common at a first glance, starting from their definitions. Digital platforms hold a central position in the business models of the largest companies in the world, transforming traditional roles in areas like employment, productivity and innovation activities (Bonina et al., 2021). Moreover, their relevance in business derives also from the fact that four of the largest firms in the world in terms of market value in late 2018 were Microsoft, Apple, Amazon and Alphabet – all platform companies (Cusumano et al., 2019). In our research on software ecosystems and digital platforms published articles in WOS data base we observe some key areas under which research collides, but with significant less overlap than anticipated. This can be explained by an evolution of research from software ecosystems and digital products toward platform ecosystem, as an emerging topic in very recent years including focus on the emerging topic of future platform economy. The research limitations include the fact that we restricted our research to article published in Web of Science data base. Future research should focus on a more inclusive approach by scanning more data bases, but also on more empirical approaches.

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