PLATFORMS: A SYSTEMATIC REVIEW OF THE LITERATURE USING ALGORITHMIC HISTORIOGRAPHY

Completed Research

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Abstract

The concept of a platform is in widespread use across a range of disciplines. This research explores the development of the platform concept through a systematic review of the literature using algorithmic historiography. The paper generates a time-based visualisation of relationships between the most cited articles in the domain. Key structural findings are triangulated using thematic content analysis, quantitative citation and network graph analysis. The analysis delineates two conceptions of platform: interior and exterior. These two classifications provide a historical lens that demonstrate the development of the platform concept over time. Furthermore, the methodology provides a generalizable systematic approach to examining the historical development, underlying structures and significant contributions of a specific knowledge domain.

Keywords: Platforms, Historiography, Historiograph, Systematic Literature Review, Citation Analysis, Content Analysis, HistCite, Pajek.

1   Introduction

The concept of a platform is becoming increasingly ubiquitous across practice and a range of academic disciplines such as management, technology and economics (Baldwin and Woodard, 2009; Thomas et al., 2014). In the broadest sense, platforms are defined as foundational products, services, or technologies upon which additional complementary products, services or technologies can be developed (Gawer, 2009). Their importance to organisations and economies has been well established (Eisenmann et al., 2006; Stabell and Fjeldstad, 1998) and they have been noted for their "pervasiveness, significant economic importance and their paradigmatic value-creation properties" (Eisenmann et al., 2011, p. 1272).

This pervasiveness, and the variable characteristics of underlying platform phenomena, have resulted in a fragmented literature base, with limited attempts at consolidation of the multiple burgeoning streams developed over the preceding decades (Gawer, 2009). Thomas, Autio and Gann (2014), as a notable recent effort, offer an alternative to Gawer's (2009) initial typology by employing a more rigorous literature review methodology. Thomas et al. (2014) furnished two key observations: firstly, the quantity of papers on platforms over the preceding two decades has grown significantly; and, secondly, there was inconsistency across the literature as to the definition of 'platform'.

Amongst Thomas et al.'s (2014) four identified literature streams, the manufacturing-based *product family* was by far the most prevalent, with 42% of total papers scrutinised falling into this category. Empirical examples examined in this category include automotive, manufacturing, consumer electronics and fast-moving consumer goods (FMCG). Despite the apparent abundance of manufacturing-based product family literature, Thomas et al. (2014) note a progressive emphasis on platform thinking in strategic management and an increasing complexity of hierarchies and systems associated with platforms. There are two key aspects of this recent review that could extend the current understanding of the platform literature. Firstly, despite the recent publication date of their review, the data only includes literature published prior to 2010. Secondly, the observed progression of literature towards specific domains could be systematically explored to elaborate underlying structural trends and commonalities over time. This research is motivated by addressing these extensions through a systematic historical examination of the diverse and rapidly evolving platform literature.

This paper employs a systematic literature review of platform articles to seek out important themes and changes in the conceptual development of the 'platform' notion over time. Using citation analysis, and illustrating this with a historiograph, the research team ascertained and plotted the top 37 journal publications in the field. The team examined the thematic flow and relations between these seminal works and discovered two key groupings based on affordances of the underlying platform phenomenon. The affordance-based platform groupings proposed by this research provide a lens for researchers to better conceptualise platforms and opportunities for further research. These thematic groupings would not have been possible without executing the systematic literature review and illustrating it historically. As such, the research team commends this methodology to researchers who are establishing their programmes of inquiry.

The paper proceeds as follows: After this introduction, the research methodology including data collection and analysis are outlined in detail. Next, the findings of our analysis are presented across three stages: algorithmic historiography; content analysis; and, quantitative key measures of centrality within the core network of platform literature. This is followed by a short conclusion, limitations of the study and suggestions for future research.

2   Methodology

To examine the development and structure of the platform literature, a systematic literature review was conducted. Approaches and guidelines for such reviews have been noted as scarce in the information systems field (Okoli and Schabram, 2010; Webster and Watson, 2002). Okoli & Schabram (2010) suggest a four stage process (Figure 1), each containing two sub-steps, when undertaking "a systematic, explicit and reproducible method for identifying, evaluating and synthesising" a body of literature (Fink, 2005, p. 3).

| 1. Planning | 2. Selection | 3. Extraction | 4. Execution |

| 1a. Purpose of the literature review | 2a. Searching the literature | 3a. Quality Appraisal | 4a. Analysis of Findings |

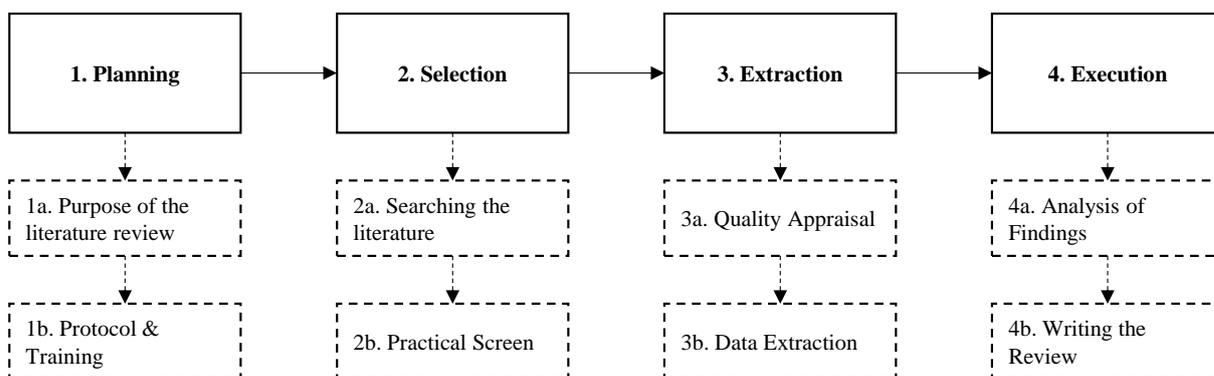| 1b. Protocol & Training | 2b. Practical Screen | 3b. Data Extraction | 4b. Writing the Review |

Figure 1.   A systematic literature review process (Okoli and Schabram, 2010)

The remainder of this section outlines our explicit approach to planning, selection and extraction through algorithmic historiography, content analysis and network analysis. Lastly, a brief outline of the execution stage is provided leading to the next section where the analysis of findings are discussed.

2.1   Planning

The initial stage of planning a literature review requires the reviewers to clearly identify the purpose of the review, establish a protocol and undertake any researcher training (Okoli and Schabram, 2010). The purpose of this review, as stated in Section 1, is the examination of historical structural trends and commonalities within the platform literature over time. Researcher training was required in the two software packages, *HistCite* and *Pakek*. Time was allocated initially to forming and documenting a collective understanding amongst the research team of the required protocol, as outlined below, and how this would assist to address the research goals.

2.2   Selection

The research team adopted a systematic approach to literature selection to encapsulate a rich context for analysing the chronological development of the platform knowledge domain. Starting with an extensive search of the ISI Web of Science Social Sciences Index database, the initial query searched for articles that had "*platform*"* in the topic field. The use of the wild card character was deliberate to ensure that all variations of the term were found. This search returned a large and diverse data set of literature (n=9,515) from the most comprehensive repository of prominent research publications available. Understandably, these results contained significant noise and needed to be further distilled to create a meaningful data set for platform-centric literature. To do this, it would have been possible to utilise additional specific keywords within ISI advanced search, however, such a process risked introducing bias towards areas of literature that the authors are accustomed to researching (Schildt et al., 2006).

As an initial practical screen for inclusion, a filter based on only journal publications listed in the *Academic Journal Quality Guide* of the Association of Business Schools (ABS) was applied. This publication provides a comprehensive listing of management literature publications with associated guidance

on relative journal quality (Harvey et al., 2010). The authors note that information systems journals and referent domain publications feature prominently in this set. A significant proportion of the data set was excluded (n=7,269), resulting in a general management-based platform literature data set of 2,246 articles. Next, this screened set of literature is appraised for quality (Step 3a) by applying exclusion criteria and applicable information is extracted systematically (Step 3b).

2.3   Extraction

For each of the remaining articles (n=2,246), the authors downloaded and read the abstract and manually applied specific exclusion criteria. These exclusions criteria were based on rejecting non-management use of the term 'platform' such as its use in geology, health, education (n=454), dictionary definitions (n=379), and finally references to specific technology artefacts that were either not material or were used as part of a research methodology; for example, a survey platform that was used for data collection (n=173). Once again, a significant portion of the data set was excluded (n=1,006). The remaining articles from this multi-step data collection and filtering process (n=1,240) comprise the core data set for this research.

Complete citation records for each of the remaining platform articles were retrieved from *ISI Web of Science* and imported into *HistCite*[1]. The most highly cited articles within the remaining literature data set on platforms were identified based on Location Citation Scores (LCS) produced by HistCite. LCS indicate how often an article is cited within a collection of research articles and thus facilitates identification of the most influential papers (Garfield, 2004). Limiting the analysis and discussion to the most influential papers is pertinent for two reasons: (1) the highest cited articles are significantly influential to the development of additional research within a domain (Griffith et al., 1974); and (2) it enables clear visualisation of a citation graph without excessive scaling (Lucio-Arias and Leydesdorff, 2008).

The authors identified the most influential papers as those with LCS greater than two standard deviations (LCS $\sigma = 4.19$) from the mean (LCS $\bar{x} = 1.03$). Two standard deviations was chosen as the cut-off for the following reasons. Firstly, it was identified that over half of the total LCS for all articles (55.83%) in the data set (n=1240) could be attributed to articles with LCS greater than 8. Secondly, the quantity of articles greater than the mean (n=160) and one standard deviation from the mean (n=67) required excessive scaling that hindered visual analysis of the algorithmic historiography output. Table 1 outlines these 37 most influential papers in descending order by LCS and provides a label number for cross reference with further HistCite output discussed later.

Label No.	Article Authors	Abbreviated Journal Title	Local Citations
341	Armstrong (2006)	RAND J ECON	68
340	Rochet & Tirole (2006)	RAND J ECON	66
69	Robertson & Ulrich (1998)	SLOAN MANAGE REV	53
338	Eisenmann, Parker & Van Alstyne (2006)	HARVARD BUS REV	32
3	Meyer & Utterback (1993)	SLOAN MANAGE REV	30
342	Hagiu (2006)	RAND J ECON	26
82	Bresnahan & Greenstein (1999)	J IND ECON	24
58	Sawhney (1998)	J ACAD MARKET SCI	20

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[1] HistCite (v12.03.17) is available through Thomson Reuters, see Garfield (2004) for a complete discussion of this tool.

Label No.	Article Authors	Abbreviated Journal Title	Local Citations
373	Gawer & Henderson (2007)	RES POLICY	19
118	Krishnan & Gupta (2001)	MANAGE SCI	19
41	Meyer, Tertzakian & Utterback (1997)	MANAGE SCI	19
197	West (2003)	J ECON MANAGE STRAT	19
383	Armstrong & Wright (2007)	RAND J ECON	18
658	Boudreau (2010)	J PROD INNOVAT MANAG	18
182	Halman, Hofer & Van Vuuren (2003)	ECON THEOR	18
144	Rochet & Tirole (2002)	MANAGE SCI	18
152	Cusumano & Gawer (2002)	MIT SLOAN MANAGE REV	17
919	Boudreau (2012)	DECISION SCI	14
327	Economides & Katsamakas (Economides and Katsamakas, 2006)	MANAGE SCI	14
263	Koufteros, Vonderembse & Jayaram (2005)	INT J PROD ECON	14
86	Muffatto (1999a)	ORGAN SCI	14
432	Gawer & Cusumano (2008)	J PROD INNOVAT MANAG	13
505	Hagiu (2009)	MIT SLOAN MANAGE REV	13
127	Meyer & Detore (2001)	AM ECON REV	13
406	Nocke, Stahl & Peitz (2007)	J ECON MANAGE STRAT	13
643	Weyl (2010)	J EUR ECON ASSOC	13
457	Peitz & Valletti (2008)	INT J IND ORGAN	12
300	Jeppesen & Frederiksen (2006)	ORGAN SCI	11
75	Muffatto (1999b)	STRATEGIC MANAGE J	11
141	Muffatto & Roveda (2002)	INFORM SYST RES	11
42	Nobeoka & Cusumano (1997)	INT J TECHNOL MANAGE	11
669	Tiwana, Konsynski & Bush (2010)	INT J OPER PROD MAN	11
159	Meyer & Dalal (2002)	J PROD INNOVAT MANAG	10
513	Corts & Lederman (2009)	J PROD INNOVAT MANAG	9
807	Eisenmann, Parker & Van Alstyne (2011)	ACAD MANAGE J	9
78	Tatikonda (1999)	STRATEGIC MANAGE J	9
253	Venkatraman & Lee (2004)	INT J IND ORGAN	9

Table 1.   The most cited articles in the platform research domain

This data set of the 37 most influential articles is used in the three activities of data extraction (Step 3b) undertaken by the research team to examine underlying historical structural trends and commonalities: (1) algorithmic historiography; (2) content analysis; and, (3) citation network analysis.

2.3.1   Algorithmic Historiography

The process of algorithmic historiography is employed to examine the chronological network of citations within a collection of research articles (Garfield et al., 2003). This implies a standard assumption that citations are a useable measure of both eminence and influence (Garfield, 1979; Ramos-Rodríguez and Ruíz-Navarro, 2004). HistCite facilitates this process programmatically and allows a historical

reconstruction of a research field with more diversity and depth of perspective than a single manual narrative reconstruction (Kranakis and Leydesdorff, 1989; Lucio-Arias and Leydesdorff, 2008). This algorithmic process generates an article level historiograph that enables visual analysis of patterns and trends over time in the platform literature. Additional, qualitative and quantitative data extraction steps were used to further analyse the platform literature.

2.3.2   Content Analysis

To develop a deeper contextual richness to the algorithmic historiography output, conventional content analysis was performed on the most highly cited platform articles. During this process categories and codes were derived from the qualitative data at the time of analysis (Hsieh and Shannon, 2005). This provides a richer understanding than a directed or summative content analysis approach that uses coding schemas that are derived prior to analysis using existing theory or research interests (Hsieh and Shannon, 2005). This process involved the researchers reading each paper to specifically examine each author's platform definition, unit of analysis and affordances.

2.3.3   Citation Network Analysis

To triangulate observations from the algorithmic historiographic, quantitative network analysis was performed on the core platform article citation network using the software program *Pajek*[2]. This software is capable of importing a number of network graph data formats, including the *Pajek NET* format used to export the citation network from HistCite. Widely used key centrality measures of degree, closeness and betweenness are calculated in Pajek to explore additional underlying structure network characteristics of the platform core literature (Freeman, 1979; de Nooy et al., 2011).

2.4   Execution

Okoli & Schabram (2010) describe the execution stage as requiring the researchers to analyse, synthesise and document the information garnered from the previous stages. Firstly, the analysis of findings involves combining the facts extracted from the literature using appropriate techniques (Step 4a). Secondly, when documenting the review in Step 4b, sufficient detail must be provided by the researchers so that the results can be independently reproduced. The next section presents our analysis of findings on the platform literature as Step 4a in our methodology.

3   Analysis and findings

The initial quantity of literature found on the broad and pervasive topic of platforms is considerable and accumulating rapidly. In 2013 alone, there were 164 (14.3%) journal articles published with the identified platform literature data set. Furthermore, there has been significant year-on-year increases in the quantity of articles published since 2008 (Figure 2), thus providing further support for this research. Whilst our data analysis examines Local Citation Scores (LCS) within the identified core platform literature, it is worthwhile noting that total cumulative Global Citation Score (GCS) for this body of research has been growing significantly in concert with quantity of articles (Figure 2). Thus highlighting the growing significance of this research to the broader scholarly community (Garfield, 2004).

This significant and sustained growth in platform literature is not surprising, given the prominence of digital products, marketplaces and technologies that have driven significant value for a number of platform operators. Research has been motivated by historically significant smartphone application mar-

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[2] Pajek (64 bit) version 4.01, along with corresponding documentation, is available at http://pajek.imfm.si/doku.php. Alternative see de Nooy et al. (2011) for an introduction on using Pajek.

ketplaces (e.g. Apple iPhone and App Store) and more recently the proliferation of 'sharing economy' platforms (e.g. Uber and Airbnb) and micro funding platforms (e.g. Kickstarter and Indiegogo).
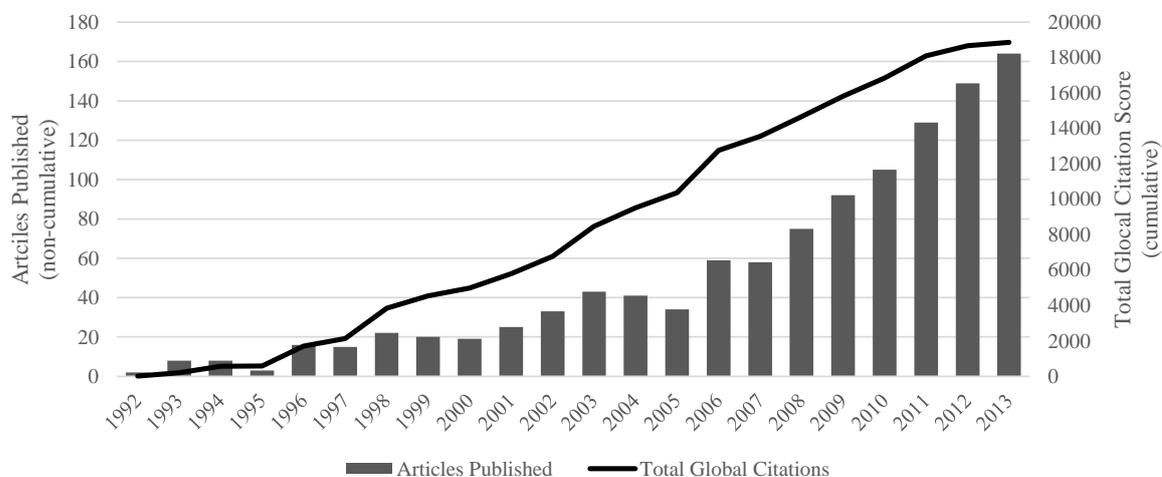

Figure 2.   Platform Article Rate of Publication and Global Citations

In the remainder of this section the following is discussed. Firstly, analysis from the algorithmic historiography will be presented including the HistCite visual output. Secondly, qualitative content analysis is presented to further explore the initial algorithmic historiography insights. Finally, quantitative citation network analysis at the individual article level is discussed to highlight important positional research.

3.1   Algorithmic Historiography

Algorithmic historiography was conducted using HistCite to examine the chronological network of citations within the platform core literature (Garfield, 2004). The results of the analysis are shown in Figure 3, which provides a citation-based visualisation of how the most cited platform articles are connected and have influenced the field over time. Key features of historiographs include circle nodes as specific articles, which have relative sizes based on LCS; network vertices as directional citations between articles; and, a measure of time against which nodes are arranged from earliest publication at the top to most recent at the bottom.

These features enabled a number of insights about the platform body of knowledge. Firstly, the research by Armstrong (2006) (node 341) and Rochet & Tirole (2006) (node 340) are clearly the two most dominant articles with strong ties of influence in the other surrounding key articles. Furthermore, what is not evident in this particular visualisation is that over half of Armstrong (2006) and Rochet & Tirole (2006) citations have been in the last three years alone. Collectively, they formulate the core of economic literature influence over the knowledge network in examining competition and pricing in two-sided markets facilitated by platforms. Secondly, there is an assumption that citation-based analysis will inherently disadvantage more recent articles as it can take considerable time to accumulate citations. However, the distribution of the nodes towards the bottom suggests that recent research is gaining prominence quickly. Examples of these later important nodes include Boudreau (2010, 2012), nodes 658 and 919 respectively, and Eisenmann et al. (2011), node 807.
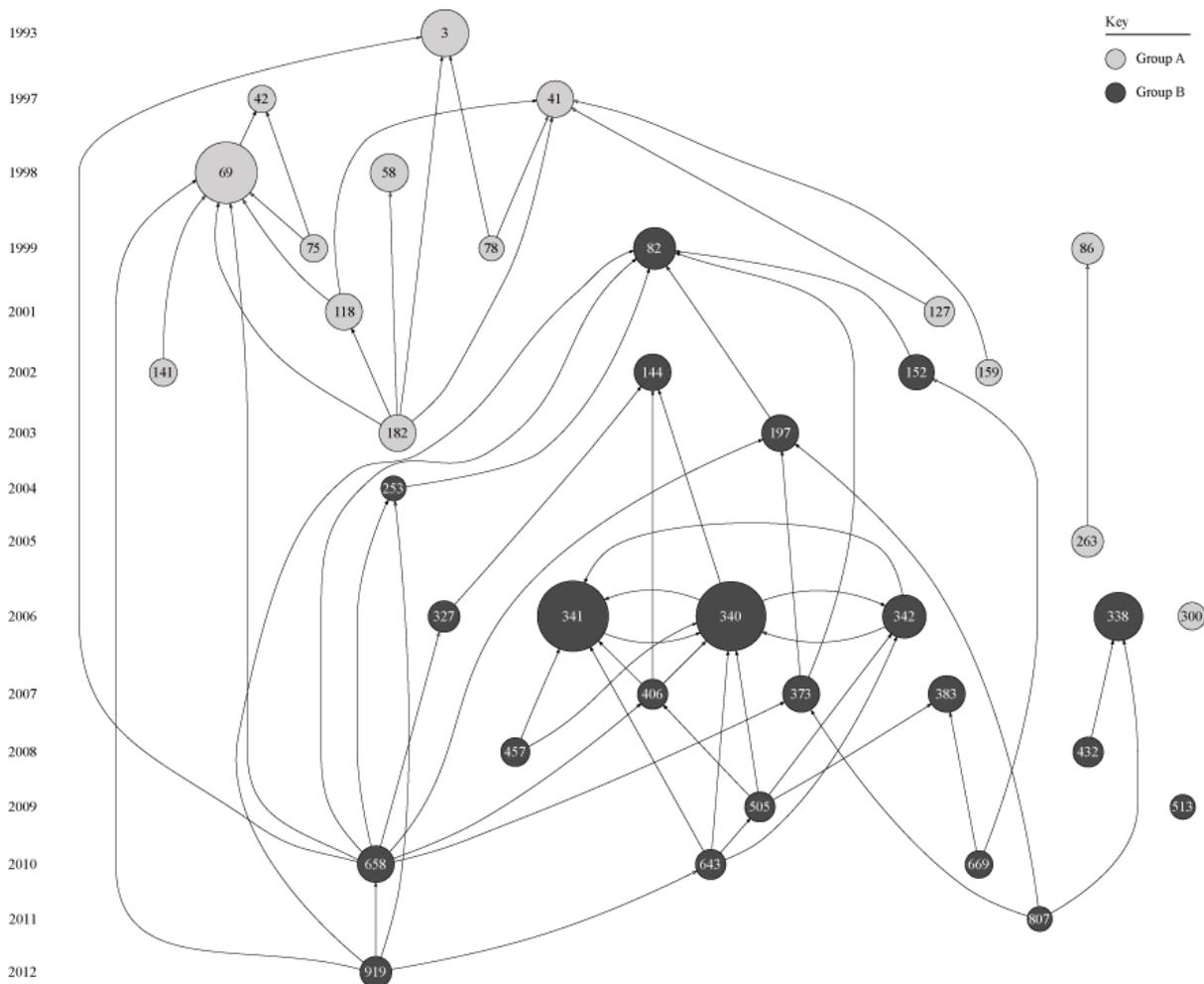
Figure 3.   Historiograph of the core platform literature

A possible explanation for the prominence of such recent research is through its relevance and proximity to more recent developments of the underlying phenomenon. Alternatively, as a multidisciplinary and emerging domain, recent research may be drawing theory, assumptions, and codified knowledge from adjacent fields as opposed to the historical precedents in the identified domain. Finally, there are two distinctive sequential groups of nodes with limited inter-linking citations. These have been shaded appropriately to highlight their positioning, with the lighter grey group of prominent articles (Group A) tightly arranged during the period of 1993 to 2003. Whilst the darker grey grouping (Group B) starts in 1999 and then solidifies from 2006 onwards. Qualitative content analysis provides additional insights to this observation of historical segregation in the platform literature.

3.2   Qualitative Content Analysis

To undertake qualitative content analysis each paper was read by the authors and codified. This process confirmed the two clear categories of platforms highlighted algorithmically. By examining each paper, it became apparent that there were fundamentally two types of platforms based on their scope of application and affordances: *Interior* and *Exterior*. Table 2 provides a summary of these two classifications and highlights key conceptual differences and definitions. These are discussed in more detail in the next sections.

Category	Units of Analysis	Affordances	Example Definitions
Interior (Group A: Light Grey)	Product Development; Organisation Capability; Planning Processes	Innovation; Modularity; Decreasing Complexity; Increasing Variety; Economies of Scope.	"Product platforms, which are component and subsystem assets shared across a product-family, enable a firm to better leverage investments in product design and development." (Krishnan and Gupta, 2001, p. 52)
Exterior (Group B: Dark Grey)	Competition; Pricing; Governance; Strategy; Complementary Participants	Two-sided markets; Network Effects; Cross-subsidisation; Economies of Scale; Participant Utility; Openness; Industry Standardisation.	"A platform enables or facilitates the interaction between the two sides provided that they indeed want to interact" (Rochet and Tirole, 2006, p. 646) "…a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses" (Gawer and Cusumano, 2008, p. 28)

Table 2.   Historiography platform categories derived from content analysis

3.2.1   Interior Platforms

Interior platform research efforts have focused on the processes, designs and capabilities of developing product families from a core underlying platform comprised of subsystems and interfaces (Meyer and DeToreb, 2001) *within* an organisation. These platforms resemble a traditional production value chain of product development through to customer consumption, as stylised in Figure 4, and are clustered around a period from 1993 to 2003.
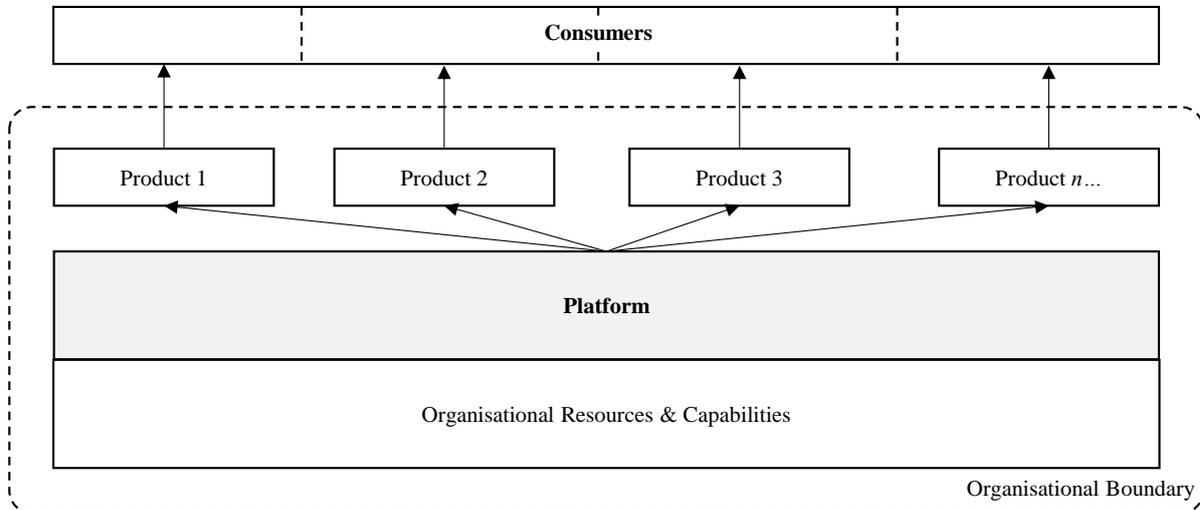

Figure 4.   Interior platform elements and configuration

The core elements of an interior platform configuration include the underlying organisational resources and capabilities that enable the planning and development of a shared product architecture based on a number of common subsystems and interfaces as a platform. The platform itself is not exposed to the customer or other suppliers as the scope is primarily for decreasing the organisational time and cost to serve differentiated product varieties to key customer segments. The most cited examples of these platforms from the literature are focused on automotive manufacturing applications (e.g. Muffatto and Roveda, 2002; Muffatto, 1999b; Nobeoka and Cusumano, 1997), other general

manufacturing case studies such as machine tools (e.g. Meyer and Dalal, 2002; Tatikonda, 1999) and finally consumer goods such as personal electronic devices (Meyer and Utterback, 1993; Robertson and Ulrich, 1998). An alternative perspective on platforms did not emerge in core literature until Bresnahan and Greenstein's (1999) longitudinal research at the turn of the century on competition in the personal computer industry. They emphasised technological competition between computer 'platforms', for example IBM System/360 and Apple Macintosh, and the historical importance of decentralisation with divided technical leadership. Thus, describing a platform extending beyond the boundaries of an organisation.

3.2.2 Exterior Platforms

Exterior platforms research focus on uses outside of the organisation that facilitate complementary product or service development by third parties (complementors) and interaction between distinct participant groups to form multi-sided markets. Commonly cited examples of the underlying phenomenon in the literature included smartphones, computers, operating systems, and marketplaces such as eBay, Amazon and payment card networks. This exterior configuration is more complex than the interior product focus visible during the 1990s literature and has been conceptualised below in Figure 5. The primary difference of exterior platform configurations is that the value chain is not as linear as an internal configuration, with the platform operator often relying on the complementary innovations to drive value (Eisenmann et al., 2006). As such, the affordances of exterior platforms discussed in the literature include mass economies of scope and scale through external complementary product and service development (Eisenmann et al., 2006), reduction of searching and transaction costs for participants (Cennamo and Santalo, 2013), cross-subsidisation of the demand or supply side participation (Rochet and Tirole, 2003), industry standardisation (Cusumano and Gawer, 2002) and network effects (Hagiu, 2006).
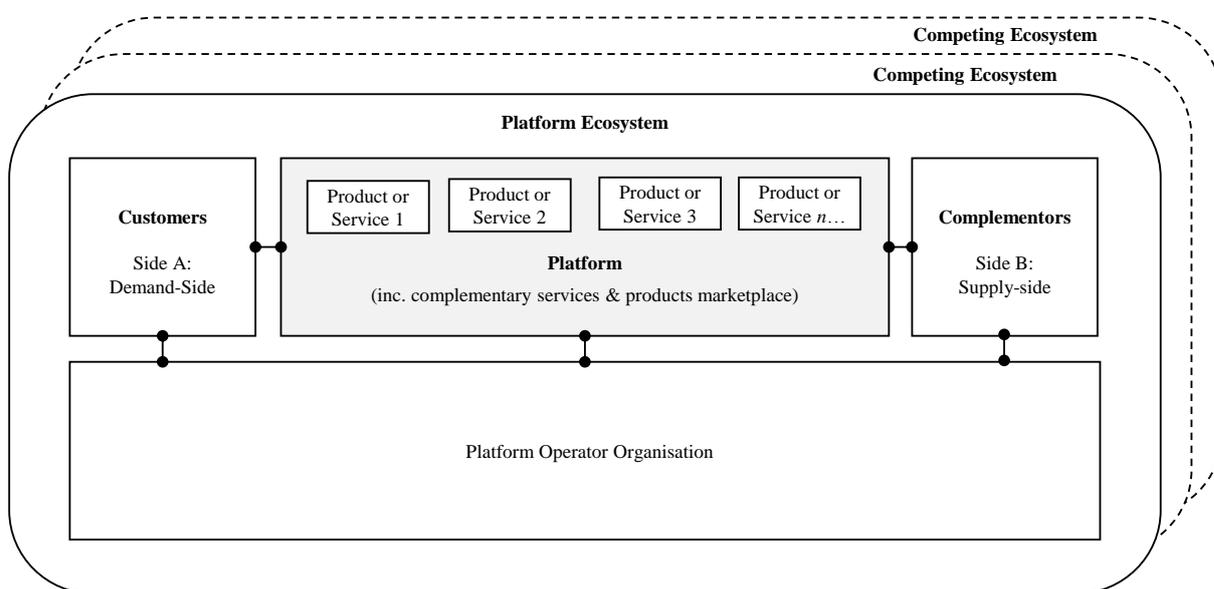

Figure 5.   Exterior platform elements and configuration

Network effects are a dominant theme within the exterior platform literature. They represent the marginal utility that a participant and platform operator derive when the quantity of participants change (Katz and Shapiro, 1985; Rochet and Tirole, 2006). *Orientation* of network effects denotes if the utility a participant derives from marketplace participant changes is *positive* or *negative*. The literature discusses positive network effects at length, as they represent increasing value of the overall platform for a user. Negative network effects are the inverse, in that they reduce the marginal utility a partici-

pant derives from additional participants joining the platform. The classic example is congestion on a network or road that degrades its performance to a state that affects a user negatively. Alternatively, it may be due to diminishing differentiation of an individual or organisation when additional participants join a platform (Evans, 2009). This type of network effect is seldom examined in literature, however, it is important to note that a platform can exhibit both positive and negative network effects simulta-neously (Tiwana, 2013). The *type* (or direction) of a network effect can either be *direct* or *indirect*. A direct network effect is when each user of such a platform directly benefits from an additional similar user joining the network. Alternatively, an indirect network effect occurs when a particular participant group in the network is impacted by a change in an alternate group of participants or complementary products (Clements, 2004; Varian and Shapiro, 1999). Indirect network effects are critical to the suc-cess of multi-sided markets and platforms as a source of significant value, particularly for the platform operator (Evans, 2009; Tiwana, 2013). In exterior platforms, these two types of network effects are often described in the context of a *side*. Direct network effects exist on the same-side of a platform, for example the positive effect associated with additional people joining an online social network (Gawer and Cusumano, 2014). Indirect network effects occur cross-side in an exterior platform such as in the case of advertisers or application developers benefiting when additional users join a smartphone plat-form (Gawer and Cusumano, 2014).

Pricing considerations are another differentiating nuance for the exterior platform literature. Scholars in this space have examined the effect of overall competitive environments and participants' abilities to multi-home on pricing considerations (e.g. Hagiu, 2006). Multi-homing is the ability for a user to participate in multiple competing platforms at the same time. For example, consumers multi-home across credit card platforms when they have both MasterCard and Visa cards. The degree to which a side of the market may be able to multi-home can have significant impacts on their bargaining power and therefore ability to influence pricing on their side (Rochet & Tirole, 2003). The same can be said for the level of switching costs. If high enough, switching costs can create a 'lock-in' effect where participants are unable or unwilling to transition to a competing platform and thereby decreasing their bargaining power (Tiwana, 2013).

From the analysis of the literature it is not always clear what authors define as a platform. This is par-ticularly evident when trying to differentiate between the marketplace that facilitates the interactions between disparate sides of a market (e.g. Apple's App Store), with the actual underlying platform (e.g. Apple's iPhone / iPad). Other specific examples of platform definition include hardware component (e.g. Intel CPU), collection of hardware components (e.g. Personal Computer), Operating Systems (e.g. Microsoft Windows) or a complex collection of product and services together (e.g. Amazon). A critical observation from the historiograph is that the definition of 'platform' appears to have devel-oped historically to reflect changes to underlying phenomena. That is to say what is considered a "platform" in the literature has moved up the technology stack, diversified and opened up to conceptu-ally exist beyond the boundary of an organisation. This observation is somewhat consistent with Sawheny's (1998) interesting commentary before the turn of the century suggesting a need for *Plat-form Thinking* across the entirety of an organisation's services, processes and markets. However, the absence of linkages between the two underlying literature citation sub-networks suggest that there are opportunities to integrate and bridge the gap.

3.3   Quantitative Structural Analysis

Analysis of three key measures of *degree*, *closeness* and *betweenness* centrality were employed to gain further insight into key structural positioning and influence of research articles within the platform knowledge network (de Nooy et al., 2011; Peteraf et al., 2013). *Degree* centrality of a node is the measure of its ties within a network (Freeman, 1979; de Nooy et al., 2011). *Closeness* centrality is based on the total distance between a given node in a network and all other nodes (de Nooy et al., 2011; Sabidussi, 1966). Larger distances between a given node and all other nodes yield lower close-ness centrality scores (de Nooy et al., 2011). These first two measures can be generalised as based on

the "reachability" of a node within a network (de Nooy et al., 2011, p. 150). The third measure, *Betweenness* centrality, indicates how often a node is present on the shortest path between other nodes in a network and is a relative measure of how important a node is to the flow of information. (Freeman, 1977; de Nooy et al., 2011).

The top 10 articles ordered by normalised *degree centrality* within the core platform literature citation network are presented in Table 3 and highlight some interesting discussion points regarding the key positioning of specific articles. Firstly a high LCS within the broader data set did not translate into a high degree score and a number of papers in the top 37 most cites had low degree centrality. This highlights that a number of key articles associated with this platform field do not share a strong and cohesive cluster of knowledge with other highly cited research (Burt, 2005). This provides further support for the proposition, discussed earlier, that the core platform knowledge domain is comprised of disparate groups.

Label No.	Article Authors	Degree	Closeness	Betweenness
658	Boudreau (2010)	0.2500	0.4197	0.0045
340	Rochet and Tirole (2006)	0.2500	0.2826	0.0073
69	Robertson and Ulrich (1998)	0.1944	0.3659	0.0040
82	Bresnahan and Greenstein (1999)	0.1667	0.3358	0.0000
341	Armstrong (2006)	0.1667	0.2693	0.0000
919	Boudreau (2012)	0.1389	0.3755	0.0000
406	Nocke et al. (2007)	0.1389	0.3439	0.0037
643	Weyl (2010)	0.1389	0.3136	0.0042
182	Halman et al. (2003)	0.1389	0.2973	0.0000
505	Hagiu (2009)	0.1389	0.2798	0.0024

Table 3.   Normalised centrality scores for the most cited platform articles (n=37)

Secondly, Boudreau (2010) has high relative centrality scores, despite a low LCS and recent publication date. These centrality scores indicate his work could facilitate a bridging and brokerage role between the disparate clusters (Burt, 2005; Goul and Fernandez, 1989; Kilduff and Tsai, 2003). Additionally, as a researcher with two articles with high closeness scores, Boudreau's (2010, 2012) research is accessible across the knowledge network and could be used for conveying information across the clusters (Burt, 2005; Kilduff and Tsai, 2003; Wasserman and Faust, 1994). Remarkably, the prominence of his work, in this bridging role, remains similarly very high when analysed within the complete population of identified platform literature (n=1240).

It is clear from this analysis that Boudreau's (2010, 2012) recent work on platform strategy and the impacts of opening a technology into an exterior platform occupies an important and influential structural position within this research domain. His work examined a retrospective data set from a transitional period in the historiography (1990 – 2004), during which he found empirical support for significant innovation rate increases when complementors were given access to a technology platform. This concept resonances with the growing recent trend of collaborative consumption in the sharing economy via digital platforms, where individuals, and more recently organisations, are choosing to open up access to resources, as demonstrated by Uber, Airbnb, DogVacay, Neighborgoods, and others (Botsman and Rogers, 2010). As a relative measure of citation accumulation rate, his two articles from 2012 and 2010 are ranked third and fourth respectively when LCS are expressed annually from publi-

cation date (LCS/t)[3] . It is anticipated that due to his structural positioning in the research domain and his underlying analysis of two central issues across both groupings (platform openness and product variety) his work will continue to feature in future efforts to bridge the divide between perspectives.

4 Conclusion and Further Research

The pervasiveness and value-creation opportunities of platforms has resulted in significant attention from a broad range of academic scholars and disciplines. This has created a fragmented literature base and limited attempts at consolidation. This research has presented a systematic process for evaluating the historical development and structural characteristics of the key platform literature through both quantitative and qualitative methods.

The contributions of this research are two-fold. Firstly, through structural analysis of the core platform literature, a key division between two historically sequential sub-domains was established programmatically. This finding is somewhat consistent with recent qualitative observations on the origins of the growing platform literature (e.g. Gawer, 2014; Thomas et al., 2014). However, the underlying classification and configurations proposed through content analysis should assist scholars, who undertake further research in this field, by providing a point of reference to identify and discuss specific target elements within complex interior and exterior platform configurations. Secondly, this research has provided a systematic method for examining the historical development, underlying structures and significant research contributions within a domain beyond that of using only total citation scores. Introducing this process to the discipline will hopefully encourage other information system researcher efforts to utilise visualisation and quantitative techniques when undertaking a review of literature for triangulation or discovery of additional insights.

Our study has several limitations. Due to the significant quantity and diversity of the platform literature, generalisations and researcher bias may be present as the study did not include any measures of cross-researcher coding correlation. A further limitation of this research is the implicit management perspective of platforms as configurations of components for the benefit of a firm. A more inclusive perspective and literature set may enrich the findings through providing alternative historiography narratives. Finally, recently published research is inherently disadvantaged in historical citation analysis methods. It is suggested, therefore, that this exercise be periodically repeated to systematically review trends in the literature domain. Subsequent examinations may demonstrate that more recent platform literature reviews, such as Gawer (2014) and Thomas et al. (2014), grow in prominence because of their relatively high outbound degree and closeness centrality measures. Longitudinal examination of such article centrality measures as an indicator of future prominence in a knowledge domain could be in interesting future research direction.

Other future directions for platform literature research include examining the diverse domain from alternative theoretical and methodological perspectives to provide additional insights as to how platform researchers have examined the phenomenon over time. Another suggested area for further research is to undertake conceptual theoretical work in establishing a unified approach between the two platform literatures streams. In particular, the authors note potential for examining the applicability of theoretical underpinnings from earlier interior-based platform literature to the burgeoning exterior-based platform phenomena. Information systems, as a diverse field of enquiry, is positioned to assert significant influence and guidance in this knowledge domain as products and services are increasingly digitised in interconnected exterior digital platforms as part of the digital economy.

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[3] HistCite calculates this measure by dividing the total LCS by the number of years since an article was published (t).

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