FinTech collaboration networks and the digital transformation of financial services

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Abstract. The diffusion of financial technologies (FinTech) in financial services has drawn worldwide attention. However, little is known about how different types of enterprises contribute to the development and transformation of this sector. In this study, we conducted a network analysis of 23,000 FinTech news articles (2008–2022) to map and characterize the global network of FinTech enterprises. We also performed a textual analysis to identify evolving FinTech trends and to differentiate collaboration dynamics between enterprise types. We found that traditional financial services providers are central to the FinTech network, while technology giants, regulatory bodies, and FinTech start-ups have gained increasing prominence. Moreover, ties between similar enterprises are stronger, although these connections have weakened over time. Textual analysis reveals shifting FinTech priorities and distinct collaboration patterns between enterprise groups.

Keywords: FinTech; collaboration; network analysis; news articles; financial services.

1. INTRODUCTION

FinTech, short for financial technology, emerges from the intersection of finance and technology. Broadly, it refers to a range of technological innovations that transform financial services. Although the interaction between finance and technology is not new, the rapid emergence and adoption of advanced digital solutions now define the modern FinTech era. Both start-ups and established technology firms have driven this disruption, modernizing many financial and accounting functions through innovative software, algorithms, and applications.

The success of FinTech firms is attributed not only to their ability to deliver fast and convenient financial services through sophisticated technologies (Puschmann, 2017; Boot et al., 2021), but also to their role in promoting financial inclusion (Salampasis & Mention, 2018), an area often underserved by traditional financial intermediaries. This competitive pressure has prompted established financial institutions, typically perceived as less adaptable to change (Hornuf et al., 2021), to develop more appealing financial solutions in response to new entrants (Kohtamäki et al., 2019). The responses of established financial institutions include developing in-house FinTech solutions, collaborating with FinTech start-ups, or gaining access to technological capabilities through mergers and acquisitions (Chemmanur et al., 2020; Murinde et al., 2022; KPMG, 2022). These companies also form strategic alliances with other established actors, as attempting to develop FinTech internally can be costly, slow, and complex (EY, 2019).

Despite the many benefits of collaboration in FinTech, traditional enterprises often remain reluctant to cooperate on high-technology solutions. This hesitation may stem, in part, from cybersecurity concerns associated with adopting new technologies (Najaf et al., 2021) and, in part, from traditional financial institutions being less agile and slower to innovate due to costly legacy infrastructures (Brandl & Hornuf, 2020). Regulatory and compliance constraints also contribute to their limited engagement in FinTech (Hornuf et al., 2021). Moreover, Vendrell-Herrero et al. (2017) suggest that innovations in digital services may discourage traditional financial institutions from pursuing their own distribution channels. Overall, the role of traditional financial service firms within the FinTech ecosystem remains underexplored.

In this paper, we identify the main actors in global FinTech and examine how they interact. We show how traditional banks, credit-card companies, FinTech start-ups, financial regulators, and other enterprise types co-exist within the FinTech network over time. Specifically, we address the following research questions:

RQ1. How can the structure and characteristics of the global FinTech network be described?

RQ2. Which enterprises occupy central positions within the FinTech network, and what collaboration patterns emerge between different types of enterprises?

RQ3. How have network structure and inter-firm collaboration dynamics evolved over time?

Collaboration in FinTech remains an underexplored area (Mention, 2019; Hornuf et al., 2021; Murinde et al., 2022). This study contributes to emerging literature by mapping the global FinTech network and shedding light on the interaction patterns of its key participants. Methodologically, it combines network analysis and content analysis of FinTech news spanning 15 years. The rest of the paper is organized as follows: Section 2 reviews literature on FinTech collaboration and network science; Section 3 describes the data and methodology used in the study; Section 4 presents the results; and the final section discusses findings and concludes the paper.

2. LITERATURE REVIEW

This section reviews the existing literature as it relates to Fintech collaboration and network analysis.

2.1. Collaboration in fintech

Collaboration is defined as "the act of working with another person or group of people to create or produce something" (Collins English Dictionary, 2019). In the business context, collaboration refers to one company cooperating with other network participants to achieve business targets and create stakeholder value (Batt & Purchase, 2004).

Although a growing number of empirical business papers have studied FinTech, literature on FinTech collaboration remains limited. Brandl & Hornuf (2020) applied a mixed-methods approach using network analysis to explore how FinTech companies and banks interact in the German market. By representing companies as nodes and connections as links, the authors presented a graphical illustration of how banks, FinTech companies, and FinTech banks are related through investments, partnerships, and spin-offs. Their findings indicate that banks are more likely to form strategic partnerships to advance new technologies than to directly integrate FinTech. The authors argue that the characteristics of new digital solutions and delayed decisions to upgrade legacy systems explain the lack of willingness of banks to fully support new digital solutions.

FinTech-bank interactions are the focus in Hornuf et al. (2021) research, that extended the findings of Brandl and Hornuf (2020) by investigating particular bank characteristics (e.g., product-related, investment) associated with bank-FinTech

alliances. Using manually collected data on bank alliances covering major banks in Canada, France, Germany, and the UK, the study examines which banks tend to collaborate with fintech firms, the intensity of such collaborations, and the forms of alliances they prefer (Hornuf et al., 2021). The authors performed regression analyses and provided evidence for alliances between banks and FinTechs based on product-related causes and, to a lesser extent, investment purposes.

Boot et al. (2021) forecast the future of banks by reviewing established trends and new developments in FinTech. More specifically, they argued that new technologies will transform banks away from their traditional business models, both horizontally (i.e., operations enabled by the bank's balance sheet) and vertically (i.e., informational and communication synergies). They noted that the following factors may speed up this transformation: specialized competitors offering horizontally integrated financial services, the easing of regulations on certain bank operations, and digital platforms offered by large technology (BigTech) firms. The authors also suggest that BigTech firms have the potential to develop ecosystems that rival banks' traditional informational and communication advantages, and they discuss the important and challenging role of regulators in fostering an environment that supports FinTech innovation.

We take a holistic approach to studying collaboration and trends in FinTech. More specifically, unlike Brandl and Hornuf (2020) and Hornuf et al. (2021), our study addresses how a wide range of FinTech enterprises (e.g., FinTech startups, traditional banks, payment processors, technology firms, regulators) come together in the network of FinTech enterprises. Furthermore, we analyze how FinTech, its actors, and its network evolved over time to suggest what the future might hold.

2.2. Network science/analysis

A network is a structure that can be graphically represented by points (or nodes) and linkages (or links) that connect the nodes. The concepts of the network, nodes, and linkages come from graph theory which uses formal mathematics, statistics, and computer science to explain information contained in the vertices (i.e., nodes) and edges (i.e., links). Mathematically, a network can be expressed in the form of a square matrix that assigns all points and linkages to rows and columns. This matrix is called an adjacency matrix since its elements express how close or adjacent any given pair is in the network. The representation of a network in the form of an

adjacency matrix allows us to understand various network properties, such as structure, the importance of each point, and other relationships.

In the social sciences, network analysis methods have been developed over several decades by coupling mathematical and statistical foundations with theoretical and empirical research. Wasserman & Faust (1994) define a social network as a social environment of a finite set or sets of members and the relationships between them. In this structure, dependency relationships arise from the unequal distribution of scarce resources among actors and the patterned allocation of these resources through their ties (Wellman, 1983). Thus, a social network is instrumental in distributing ideas, information, and other organizational resources between its members (Kempe et al., 2003; Lea et al., 2006).

Since it borrows from multiple disciplines, social network analysis is a sophisticated area of research. However, at its core, it entails analyzing relationships between interacting entities within a social system. It is a broad intellectual approach to the study patterns of the ties linking organizations, individuals, or groups (Wellman, 1983). Patterns and relationships in a network can be analyzed through various analytical and visual techniques, as described below.

The widespread use of computers and programming by academic researchers has accelerated the application of social network analysis in social science disciplines. In management and business research, researchers have used network analysis in project management, supply chain management, and strategy research. Chinowski et al. (2010) analyzed survey data collected from full-service engineering companies that exhibit high levels of collaboration, to understand the characteristics of high-performance teams. To accomplish this goal, the authors obtained density and centrality measures (see Appendix A for definitions) for discipline managers tasked with the implementation of the company's strategic vision. Based on calculated measures, they identified the level of interaction within each team and the importance of each discipline manager to lead and communicate in high-performance environments. The study demonstrates that network analysis can effectively be used to examine the role of trust, communication, and knowledge transfer in enhancing the performance of project teams.

In the financial services industry, Minoiu and Reyes (2013) performed a network analysis of geographical linkages in the global banking system. Participants (or actors) in this study included 184 countries responsible for cross-border banking

and capital flows from 1978 to 2010. The authors used such measures as network density, node centrality, and connectedness to describe the structural properties and dynamics of the global banking network before and after the global financial crisis of 2008. In addition, the analysis ranked the participants (countries) based on their importance to the global network. This helped monitor the relative position (or stability) of leaders (important nodes) in times of financial crises. As a major direction for future research, Minoiu and Reyes (2013) indicate the need for studies of network typology that cover a greater number of asset classes and indicators.

3. DATA AND METHODOLOGY

3.1. Data

This study uses data from Finextra – a prominent and independent source of information for the global FinTech community (Finextra Research, 2022), that provides news, press releases, and research related to financial technology through its finextra.com website.

As a major financial technology newswire, Finextra has been providing news about FinTech and other firms around the world since 2003. Each news article includes details regarding related firms, news release date, channels, and keywords. Appendix B provides a sample news article from Finextra. The number of related firms, which are enterprises mentioned in the article, ranges from one to several.

This study uses FinTech news articles published between 2008 and 2022. The financial crisis of 2008 marked the start of FinTech 3.0 that saw unprecedented growth in the use of technologies such as smartphones, applications, and application programming interfaces (APIs) in financial services (Giglio, 2021; Paul & Sadath, 2021). During the study period, 23,266 FinTech news articles were published. The number of news articles, enterprise mentions, unique enterprises, unique channels, and unique keywords are provided in Appendix C. Enterprises mentioned in FinTech news articles included payment processing companies such as Visa and Mastercard, commercial banks such as Barclays and Citi, financial regulators such as the Financial Conduct Authority (FCA) and European Central Bank (ECB), FinTech start-ups such as Monzo and Revolut, and other entities. Appendix D lists the top 50 enterprises by number of mentions in FinTech news throughout the study period. Channels in FinTech news refer to the nature of business conducted by the named enterprises (e.g., wholesale banking, retail banking, cryptocurrency).

Keywords provide more specific information regarding the primary topic of each FinTech news article (e.g., cards, trade execution, blockchain, artificial intelligence). We performed a cluster analysis[1] based on the channels and keywords included in the FinTech news (see Appendix E). This segmentation of FinTech enterprises provided high-level descriptions of FinTech groups for the 15-year study period. Almost half of the news articles belong in Segment 1 (49%), characterized by such channels and keywords as wholesale banking, regulation and compliance, trade execution, dealing rooms, mergers and acquisitions, and blockchain. Segment 2 (28%) and Segment 3 (23%) are similar in that retail banking is the main channel in both. However, the predominant keywords in Segment 2 included start-ups, mobile and online, artificial intelligence, and open APIs, while those in Segment 3 included payments, security, mobile and online, cards, start-ups, and mobile.

3.2. Methodology

The methodology was twofold: first, we conducted a FinTech network analysis, followed by a textual analysis of FinTech news. Our FinTech network analysis entailed the investigation of the FinTech network and the evolution of its properties in different periods using network science. This analysis helped answer the first research question (RQ1) and, partially, the second research question (RQ2). Subsequently, we performed a textual analysis of FinTech news content using natural language processing (NLP) to generate insights about FinTech and about FinTech collaborations. These insights provided more answers to the second research question (RQ2) and addressed the third research question (RQ3).

FinTech Network Analysis

We started by constructing the FinTech network based on the adjacency matrix of enterprises mentioned in the FinTech news for each year in the period 2008–2022. Next, we explored the features and shape of the FinTech network for various periods. These network attributes include nodes (enterprises), edges (a connection between enterprises), isolates (enterprises not connected to the network), and degree (average number of connections per enterprise) of the network. Appendix A provides the definitions of measures used in the study. Next, we examined some of the most connected enterprises in the network of FinTech firms to gain insight into

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[1] k-means clustering using principal components identified from channels and keywords in new articles.

connections between enterprises. Finally, in the analysis of FinTech network properties, we discovered the most important players based on their centrality or popularity measures.

Textual Analysis of FinTech Articles

We investigated FinTech news content to identify differences in the patterns of themes and keywords in different periods and among different enterprise types. In this analysis, we applied NLP to extract quantifiable features of textual data that we transformed into a Tf-Idf matrix. The textual features, which were words and phrases,[2] were then used in a set of logit models, defined as follows:

$$Time = \alpha + \alpha_1 TFIDF + \varepsilon \qquad (1)$$

where *TFIDF* is a vector of textual features and the dependent variable *Time* (2020, 2021, 2022 =1) refers to two sets of years: 2008–2019 and 2020–2022. Based on the associations between the textual features and the dependent variables, we were then able to identify words and phrases that described FinTech news in more recent years versus in earlier years.

$$TradB = \beta_0 + \beta_1 TFIDF + \varepsilon \qquad (2)$$

where the dependent variable *TradB*(1 if traditional bank 0 if FinTech start-up) refers to communication between two sets: collaboration between established banks and collaboration between FinTech start-ups.

$$IncPP = \delta_0 + \delta_1 TFIDF + \varepsilon \qquad (3)$$

where the dependent variable *IncPP*(within=1) refers to communication between two sets: communication between established payment processors within the same network and in different networks.

Since independent variables in the defined logit models are textual features representing words and phrases used in FinTech news, the sign (positive or negative) and the significance of each dependent variable could be used to show how important a word or phrases is and how it is related to the dependent variable.

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[2] Phrases are extracted using an n-gram model.

For example, if the word/variable "cryptocurrency" was significant and positive in model (1), then more recent FinTech news (2020, 2021, and 2022) would discuss "cryptocurrency" among other things, which was not the case for news from earlier years.

4. RESULTS

4.1. FinTech network analysis

FinTech Network from 2008 to 2022: Overall Properties and Isolates

Table 1 provides information on the counts of nodes (or enterprises), edges (or connections), and isolates over time. Overall, there is an increasing trend in each of the three metrics. This is an indication of the growing number of FinTech enterprises and connections. The table also presents the percentage of isolates and the network degree in the study period.

Year	# of Nodes	# of Edges	# of Isolates	% of Isolates	Network Degree
2008	568	1,952	65	0.11	3.44
2009	496	1,704	72	0.15	3.44
2010	449	1,297	65	0.14	2.89
2011	380	1,244	71	0.19	3.27
2012	376	725	73	0.19	1.93
2013	402	1,145	84	0.21	2.85
2014	364	754	90	0.25	2.07
2015	370	720	82	0.22	1.95
2016	396	1,024	92	0.23	2.59
2017	486	872	108	0.22	1.79
2018	702	1,380	170	0.24	1.97
2019	858	1,702	220	0.26	1.98

2020	1,076	1,422	369	0.34	1.32
2021	1,219	2,423	436	0.36	1.99
2022	1,056	1,477	367	0.35	1.4

Table 1. FinTech network characteristics (2008–2022)

Figure 1, which graphically represents the information in Table 1, reveals that the proportion of unconnected enterprises has been increasing. This is one of the factors leading to lower levels of connectedness within the network. While some isolate enterprises are disappearing from the FinTech network, others are becoming more entrenched. For example, there were 185 isolate enterprises in the three years from 2010 to 2012. Ten years later, in the three-year period from 2020 to 2022, 100 (54.1%) of these isolate enterprises had disappeared from the network and 85 (45.9%) remained. Of these remaining isolate enterprises, none stayed as isolates: 31 now (36.5%) had one connection and 54 (63.5%) had two or more connections. Most of the 54 deeply connected enterprises that had not previously been connected to other enterprises in the network were start-up firms[3] founded from the mid-2000s to the early 2010s.
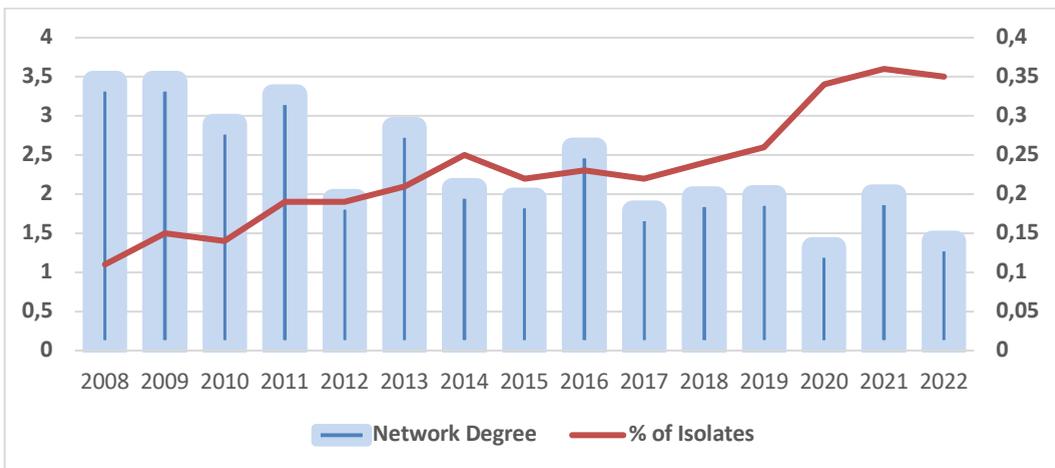

Figure 1. Network degree over time

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[3] Examples include Adyen, eToro, GoCardless, Jumio, Nutmeg, Payoneer, SumUp, Wise, Zopa.

Most Connected Enterprises and Their Similarities

We analyzed the main actors and the connections between them in the network of FinTech enterprises. Figure 2 visualizes the links between enterprises with more than 20 connections. The more connections an enterprise has, the more central its position in the network. The width of each link is determined by the strength of connection between two enterprises connected by the link.
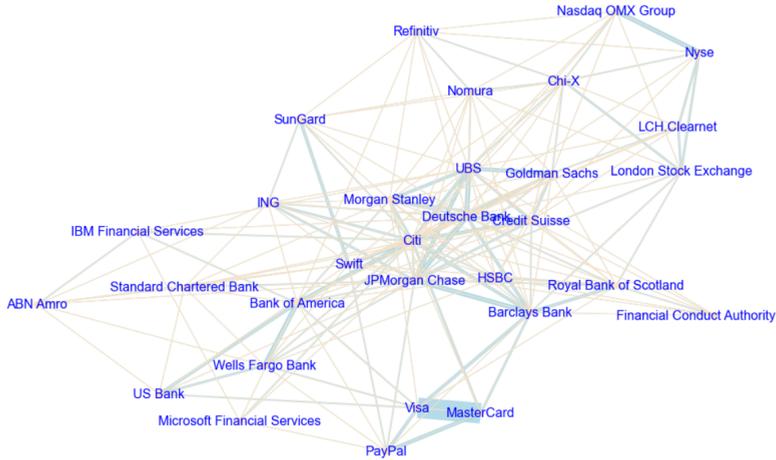

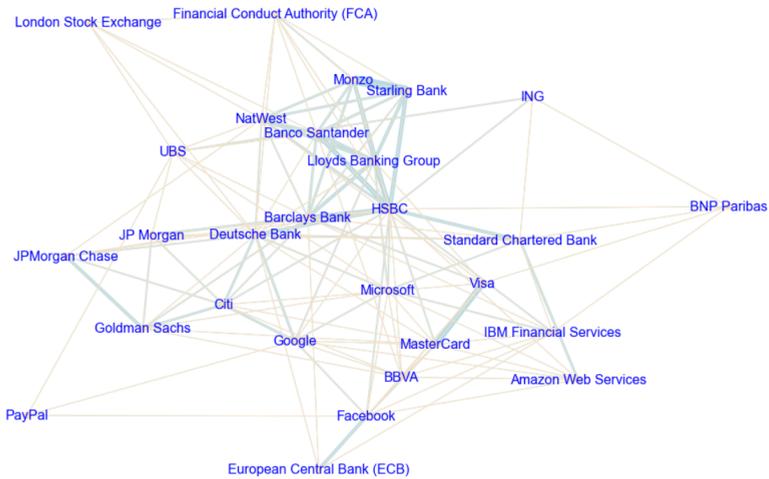Figure 2. The network of most connected enterprises in 2010 versus 2022. Panel A: The network in 2010

Figure 2. The network of most connected enterprises in 2010 versus 2022. Panel B: The network in 2022

Panel A and B of Figure 2 present a pictorial representation of the evolution of the FinTech network from 2010 to 2022. Both networks are dominated by large traditional financial institutions, i.e., commercial banks, wholesale banks, and payment processors. Citi, Visa, MasterCard, Deutsche Bank, Barclays Bank, JPMorgan Chase, HSBC, Goldman Sachs, UBS, and others are central figures in both networks. European financial regulators, such as the Financial Conduct Authority (FCA), are present in both 2010 and 2022, and the European Central Bank (ECB) is present in 2022. However, a feature that distinguishes between the two networks is the involvement of tech giants such as Google, Facebook, Amazon, and Microsoft in the network of FinTech firms in 2022. Consistent with Boot et al. (2021), this is indicative of the increasing involvement of large information technology (IT) companies in FinTech, and their alliance with established financial services providers.

Connections between enterprises in the same type of business appear to be strong, although with some caveats. For example, the link between Visa and MasterCard is the widest (i.e., strongest) in the 2010 network, although this connection weakened noticeably in 2022. The thicker links in Panel B of Figure 2 also highlight strong connections within the commercial bank sector and the wholesale bank sector in the two networks.

Next, we examined the overall connections of each enterprise to quantify the similarity between some of the key actors in the FinTech network. We also observed how these similarities have changed over time. Table 2 presents Jaccard similarity scores between the 10 most connected enterprises in 2010 and 2022.

Jaccard similarity scores in the lower triangular portion (to the left of the main diagonal) of Table 2 shows how similar each pair of enterprises is in terms of its own network in 2010. All values are color coded – i.e., the higher the similarity/Jaccard score the higher the color intensity. Some of the most similar pairs are HSBC and Barclays Bank (0.37), Visa and MasterCard (0.31), JPMorgan Chase and Swift (0.31), Citi and Goldman Sachs (0.31), and JPMorgan Chase and Barclays Bank (0.22).

	Mastercard	Citi	Visa	JPMorgan Chase	Barclays Bank	HSBC	NatWest	FCA	Swift	Goldman Sachs
Mastercard	1.00	0.10	0.14	0.04	0.09	0.17	0.04	0.05	0.09	0.09
Citi	0.05	1.00	0.07	0.16	0.14	0.14	0.09	0.03	0.08	0.21
Visa	0.31	0.08	1.00	0.03	0.05	0.11	0.04	0.07	0.04	0.07
JPMorgan Chase	0.05	0.20	0.09	1.00	0.14	0.08	0.08	0.05	0.11	0.16
Barclays Bank	0.13	0.15	0.12	0.22	1.00	0.08	0.08	0.05	0.11	0.16
HSBC	0.07	0.17	0.10	0.22	0.37	1.00	0.25	0.13	0.08	0.10
NatWest	0.03	0.07	0.04	0.03	0.21	0.22	1.00	0.19	0.07	0.07
FCA	0.02	0.16	0.05	0.13	0.16	0.20	0.12	1.00	0.09	0.06
Swift	0.04	0.22	0.07	0.31	0.12	0.17	0.00	0.06	1.00	0.05
Goldman Sachs	0.05	0.31	0.07	0.19	0.17	0.19	0.05	0.19	0.16	1.00

Table 2. Jaccard Similarity Heatmap 2010 (left of the main diagonal) versus 2022 (right of the main diagonal)

The upper triangular portion (to the right of the main diagonal) of the figure displays similarity scores in 2022. Here the most similar pairs are HSBC and NatWest (0.25) and Citi and Goldman Sachs (0.21). Note that the similarity values are lower compared to the earlier period. In fact, the average similarity score in 2010 was 0.14, whereas in 2022 it was 0.10.

Central Enterprises in the Network of FinTech: Centrality Measures

In this section we examine node centrality measures to analyze how important an enterprise is within the network of FinTech enterprises. Four panels in Appendix F present the top 30 enterprises based on their degree, eigenvector, betweenness, and closeness centrality measures for 2008, 2015, and 2022. These seven-year intervals were chosen to observe the popularity, importance, and influence of enterprises over time.

Based on degree centrality (Appendix F1), most connected enterprises are older financial institutions such as MasterCard, Citi, Visa, JPMorgan Chase, Barclays Bank, and HSBC. Appendix F2 shows the most influential enterprises as measured by eigenvalue centrality. Citi was top of the list in all three periods, while most of the list was comprised of established traditional financial institutions in each period. Unlike degree centrality, eigenvalue centrality shows fewer start-up firms. This is somewhat expected as it might be less likely for relatively newer firms to create

connections with core nodes in the network. Appendix F3 ranks enterprises by closeness centrality which measures how close an enterprise is to other enterprises in the network. Similar to the previous centrality lists, this list is dominated by the traditional payment processors and banks, with a few exceptions. Technology firms Google and Amazon were among the top 10 enterprises in 2022. This implies that an increasing number of FinTech firms are collaborating with IT firms. This is also true for betweenness centrality (Appendix F4) which measures the number of times an enterprise is between two other enterprises; technology giants Microsoft and Google were among the most central enterprises in 2022. Moreover, start-up FinTech firms have more betweenness centrality in Appendix F4, especially in 2022. This points to the important influence of firms such as Klarna, Monzo, Starling Bank, Coinbase, and Revolut in the flow of information in the network.

These centrality measures point to a few obvious trends. For example, stock exchanges such as Nasdaq, NYSE, and the London Stock Exchange have become less central over time, while cryptocurrency exchanges such as Coinbase and Binance appeared in the network of FinTech enterprises in 2022. Another trend is that technology giants such as Microsoft, Google, Facebook, and Amazon have become among the most central figures. Similarly, the role of supervisory authorities such as the Financial Conduct Authority (FCA) and the Bank for International Settlements (BIS) has risen in the network.

4.2. Textual analysis of fintech articles

So far, we have investigated the network of FinTech enterprises based on their co-occurrences in FinTech news articles. In this section, we explore the content of each news story to provide additional insights regarding the evolution of FinTech and the characteristics of collaboration between various types of enterprises in the FinTech network.

Recent Years versus Earlier Years

Our FinTech news trend analysis started by counting the frequency of keywords included in FinTech news from 2008 to 2022. Appendix G provides the 10 most frequently used keywords for each year. From 2008 to 2013, most news stories included keywords such as "cards," "dealing rooms,"[4] "reporting and compliance," "legal," and other trade execution related keywords. From 2014 to 2019,

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[4] Also known as the front office or trading floor.

"innovation," "mobile and online banking," and "blockchain" were among the dominant keywords. From 2020 to 2023, "open-APIs," "chatbots," "BNPL," and "artificial intelligence" started to emerge. We performed news content analysis using NLP techniques to further analyze the period 2020–2023. Figure 3 displays the results of logit model (1) in a word cloud.

Figure 3. 2010 versus 2022 news summaries

The word clouds in Figure 3 highlight the most significant words and phrases that differentiate FinTech news in the period 2020 to 2022 (left) from the earlier period (right). Until the last three years of the study period, most FinTech news focused on mobile devices, online and electronic options, enabling customers, trading, internet, cryptocurrency, virtual currency, currencies, ATM, wearables, malware, theft, blockchain, etc. A few of these themes (e.g., cryptocurrency) also appear in the 2020–2022 news; however, the final three years can primarily be characterized with such words and phrases as COVID-19, metaverse, stablecoin, CBDC,[5] digital asset, BNPL, cloud, open banking, embedded finance, open finance, banking technology, sustainability, ESG, quantum, AI, technology unit, spend management, etc. Although a few themes in the earlier period reappear (e.g., different words and phrases describing cryptocurrency) in 2020–2022, most of the themes of the latest period are unique to that period.

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[5] Central Bank Digital Currency

Collaboration between Traditional Banks and FinTech Start-ups

Our second logit model (Eq. 2) compares traditional banks and FinTech start-ups using the news articles in which each group is mentioned.[6] The most significant words and phrases that describe collaboration between traditional banks are presented on the left side of Figure 4. The main topics in these news articles referred to bank operations such as branch, ATM, credit cards, investment banking, and bank service; bank stakeholders such as clients and staff; systems and payment options such as lending platforms, contactless payment, biometrics, mobile payment, and virtual and digital channels; possible initiatives such as collaborating, improving, launching, managing, and letting customers access/use; data sources such as account information, financial data, and data centers; and technology items such as AI, quantum, digital, and innovation.

Words and phrases associated with FinTech news that described collaboration between FinTech start-ups are shown on the right side of Figure 4. As might be expected, the phrase "challenger bank" is mentioned most frequently in these news articles. Unlike traditional banks, the primary stakeholders of FinTech start-ups are users, as highlighted in the word cloud.
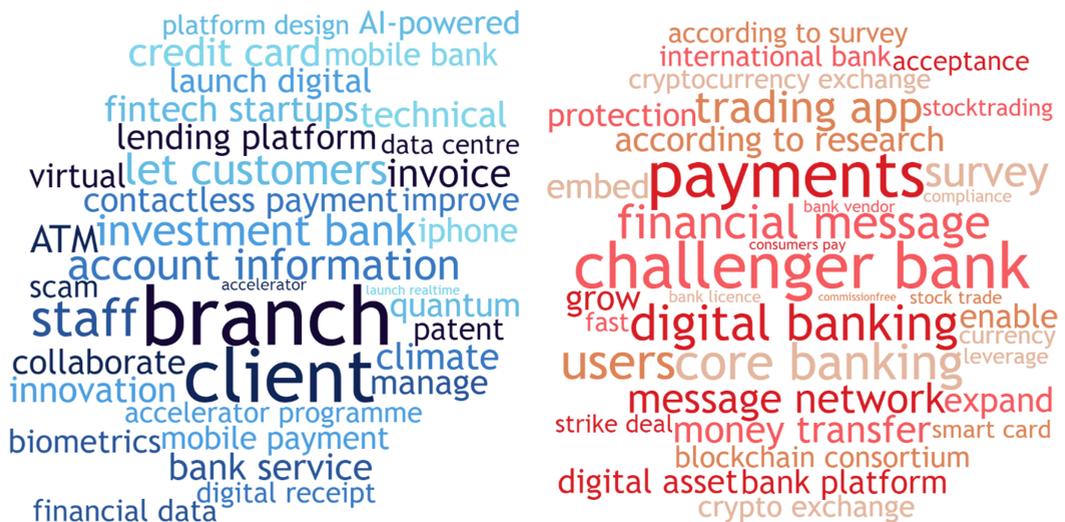

Figure 4. Traditional banks versus FinTech start-ups

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[6] Two sets of FinTech news articles were identified based on references to traditional banks only or to FinTech start-ups only.

Payments, money transfers, and digital banking were some of the most mentioned topics relating to traditional banking services. Another important set of topics described the investing services (e.g., trading app, digital asset, stock trading) offered by FinTech start-ups or neobanks.[7] Verbs such as enable, embed, expand, leverage, and grow might be indicative of the focus of neobanks. Phrases such as "according to research" and "according to survey" might signify the data- and research-oriented approach of neobanks. Another common phrase for neobanks was "strike deal," which is perhaps indicative of mergers and acquisitions involving neobanks.

Internal versus External Payment Processor Collaboration

As the centrality measures (Appendix F) show, payment processors such as Visa and MasterCard have been central in the network of FinTech enterprises. This part of the textual analysis compared collaboration between major payment processors (i.e., Visa, MasterCard, and American Express) to collaboration between payment processors and the rest of the FinTech network. Figure 5 visualizes the results of the logit model formulated in Equation 3.

Figure 5. Payment processors (Mastercard, Visa, and American Express) internal and external networks based on news summaries.

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[7] Neobanks, sometimes referred to as "challenger banks," are fintech start-ups that offer apps, software, and other technologies to streamline mobile and online banking (https://www.forbes.com/advisor/banking/what-is-a-neobank/).

The main collaboration words and phrases in the communication between payment processors and other network participants are presented on the right side of Figure 5. Mobile, bank, platform, launch, teamed, joined, business, funding round, innovation, contactless mobile, mobile wallet, agreement, blockchain, and pre-paid are some of the most significant elements in this communication. Communication between payment processors is highlighted in the right portion of Figure 5. Here, the main words and phrases include interchange fees, security, Wikileaks, settlement, fee, NFC payments, retailers, migration, security, EMV chip, contactless bank, security breach, signature, token, favor, and schemes. As expected, these collaboration elements are much more focused on payment processing. In addition, the main topics of communication between payment processors seem to revolve around fees, settlement, security, and payment methods.

5. DISCUSSION AND CONCLUDING REMARKS

As demonstrated in the analysis, this study defines the FinTech network as a dynamic system of interconnected enterprises that collaborate to advance technological and innovative capabilities. The co-occurrence of enterprises in FinTech news articles reflects the strength of connections within this network. Over the past 15 years, participation in the network has expanded to include a broader range of enterprises. However, the overall level of connectedness has declined, while the number of unconnected enterprises (isolates) has increased. This trend can be attributed to the continuous entry of new members, with isolates from previous years gradually becoming integrated over time.

Our findings indicate that enterprises operating in similar lines of business not only cooperate more intensely with one another but also display comparable collaboration patterns. Nevertheless, the degree of cooperation between traditional financial institutions has diminished, while partnerships between these institutions and other types of enterprises have intensified. This is consistent with the view that established institutions benefit from improved regulatory conditions (Daud et al., 2022; Sun et al., 2022) and compensate for their late adoption of financial inclusion and digitization by forming alliances beyond their traditional networks (Brandl & Hornuf, 2020; Feyen et al., 2021).

Although FinTech firms pose a threat to the market share held by traditional financial institutions (Nienaber, 2016; Goldstein, 2019), they have also encouraged legacy banks to become more engaged in the FinTech network (Klus et al., 2019;

Feyen et al., 2021; Murinde et al., 2022). Greater participation of traditional financial intermediaries enhances both operational efficiency (Hendershott et al., 2021) and financial stability (Fung et al., 2020; Daud et al., 2023). Consequently, traditional financial service providers, which are constantly seeking collaborative opportunities, are deeply embedded within the FinTech network. In addition to cooperating among themselves, they have established strong ties with large software and technology firms. This aligns with the growing use of BigTech solutions (e.g., APIs, ecosystems, and cloud computing) in financial services as traditional financial institutions transition to online environments (Huang, 2018; Boot et al., 2021). Another key group of actors in the FinTech network are start-ups, which leverage the reputation and resources of existing actors (Klus et al., 2019) in exchange for providing technological innovation and disruptive solutions (Chemmanur et al., 2020).

Our network centrality analysis also highlights the rising prominence of regulatory agencies and cryptocurrency exchanges. Consistently, our textual analysis reveals that cryptocurrencies and digital assets are among the most discussed topics in recent FinTech news. This domain has attracted the attention of policymakers tasked with designing new regulations to govern cryptocurrency activities. More broadly, the growing importance of regulatory bodies underscores the increasing role of regulation in shaping both challenges and opportunities within the FinTech ecosystem (Sun et al., 2022).

The deep involvement of established financial institutions in FinTech is particularly evident in the domain of payments. Visa and Mastercard are among the most connected enterprises in the network, and their mutual collaboration is one of the strongest observed. They are also the top two companies linking other enterprises based on betweenness centrality, reflecting a high degree of engagement in FinTech developments. According to our content analysis, collaboration between payment processors (e.g., Mastercard, Visa, and American Express) and other FinTech participants centers around teaming up, investment initiatives, and new product launches.

Our textual analysis comparing news that mentions traditional banks with news that mentions FinTech start-ups reveals distinct elements of collaboration. Traditional banks tend to focus on branch operations, platform development (e.g., lending platforms), fraud prevention, and financial data management (e.g., account

information, invoices, biometrics), as well as payment options. In contrast, FinTech start-ups collaborate more on money transfers and payments, digital services and mobile applications (e.g., trading, messaging), user experience, digital assets and blockchain, crypto exchanges, and research initiatives. As older financial institutions adopt more online alternatives to traditional banking operations (Hendrikse et al., 2023), the differences between banks and FinTech start-ups are likely to narrow (Huang, 2018). The COVID-19 pandemic accelerated this digital shift (Fu & Mishra, 2022), becoming a dominant topic in recent FinTech news.

This paper offers a novel approach to defining and examining the FinTech network over time. Our findings contribute to the literature on business network analysis and FinTech collaboration. The insights generated here can help diverse enterprises, regardless of their level of participation in the FinTech network, develop effective collaboration strategies. Nonetheless, despite the extensive international coverage of Finextra Research, our dataset remains limited to a single news source. Future research could address this constraint by aggregating FinTech news from multiple databases and more reliably removing redundant publications.

Another limitation lies in the selective focus of our analysis on specific collaboration patterns. Future studies could expand this scope by examining a broader range of connections and collaboration elements within the FinTech ecosystem.

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Appendix A
Measures and Definitions

Variable/Measure	Definition
Adjacency Matrix	A square matrix representing a FinTech network in a mathematical form which shows connections between all enterprises in the network.
Centrality	An importance measure of an enterprise in a FinTech network. It is a popularity measure.
Degree Centrality	A centrality measure that shows the number of connections to an enterprise. The higher the degree, the more central the enterprise is.
Eigenvector Centrality	A centrality measure that considers the importance of an enterprise's immediate neighbors to determine how influential the enterprise is in the FinTech network.
Betweenness Centrality	A centrality measure based on the number of times an enterprise is between two other enterprises.
Closeness Centrality	A centrality measure that quantifies the closeness of an enterprise to many other enterprises in the FinTech network.
Node	An enterprise mentioned in a FinTech news article. Nodes represent the objects of interest in a FinTech network.
Edge	A connection between two enterprises based on their co-occurrence in a FinTech news article.
Isolate	An enterprise that is not connected to any other enterprise in the FinTech network. Isolates are generated from news articles where only one enterprise is mentioned.
Network Degree	The average number of connections per enterprise in a FinTech network.
Jaccard Similarity	A similarity measure between connected components of two enterprises.

Appendix B
Sample News Article Published on Finextra

Mastercard and Coinbase partner to let people buy NFTs with cards

18 January 2022

Related Companies

MasterCard >

Coinbase >

Lead Channel

Payments >

Channels

Cryptocurrency >

Retail Banking >

Keywords

Cards >

Editorial | what does this mean?

Mastercard is joining forces with Coinbase to enable people to buy NFTs with their debit and credit cards.

Coinbase recently joined the NFT party, outlining plans to build a decentralised marketplace where users can mint, collect and trade non-fungible tokens.

However, the firm acknowledges that the process of buying an NFT can be daunting for novices, requiring them to open a crypto wallet, buy crypto, then use it to purchase the NFT in an online marketplace.

The firm is working with Mastercard to classify NFTs as "digital goods" and unlock a new way to pay using cards.

Raj Dhamodharan, EVP, digital asset and blockchain products and partnerships, Mastercard, says: "We're working to make NFTs more accessible because we believe tech should be inclusive.

"When more people are included in new technologies, it spurs innovation, helps economies grow and expands choices for consumers."

Source: Finextra Research (2022)

Appendix C
Details of News Articles by Year (2008–2022)

Notes: The totals represent unique sums for unique enterprises, unique channels, and unique keywords.

Year	News articles	Enterprise mentions	Unique enterprises	Unique channels	Unique keywords
2008	1,502	2,561	568	9	70
2009	1,391	2,172	496	9	66
2010	1,208	1,826	449	9	66
2011	1,139	1,713	380	10	66
2012	1,112	1,497	376	11	62
2013	1,156	1,451	402	11	70
2014	1,252	1,346	364	11	63
2015	1,409	1,476	370	13	64
2016	1,634	1,847	396	14	69
2017	1,537	1,867	486	15	72
2018	1,635	2,264	702	15	74
2019	1,826	2,597	858	17	83
2020	2,175	3,016	1,076	19	85
2021	2,222	3,230	1,219	19	93
2022	2,068	2,810	1,056	19	100
Total	**23,266**	**31,673**	**3,328***	**19***	**115***

Appendix D
50 Most Commonly Mentioned Enterprises in News Articles (2008–2022)

Enterprise	Mentions
Visa	792
MasterCard	778
Barclays Bank	662
Citi	484
JPMorgan Chase	437
PayPal	429
HSBC	421
Swift	417
Financial Conduct Authority (FCA)	314
Lloyds Banking Group	301
Deutsche Bank	298
Royal Bank of Scotland	294
Goldman Sachs	293
IBM Financial Services	282
Banco Santander	264
Nasdaq OMX Group	260
Google	258
Commonwealth Bank of Australia	241
London Stock Exchange	240
Bank of America	233
ING	228
BBVA	226
European Commission	225
NatWest	207
Nyse	206
European Central Bank (ECB)	199
Refinitiv	199
UBS	196
Facebook	195
Securities and Exchange Commission (SEC)	185
Bank of England	180
American Express	176
Westpac	175
Standard Chartered Bank	174
Wells Fargo Bank	169
National Australia Bank (NAB)	167
BNP Paribas	165
Starling Bank	153
Deutsche Börse	146
Revolut	146
ANZ Banking Group	144
Monzo	140
Credit Suisse	136
Nationwide	134
Finastra	132
ABN Amro	128
Ripple	126
Société Générale	125
Temenos – The Banking Software Company	125
Federal Reserve Board	121

Appendix E
Clusters of Enterprises based on News Channels and Keywords
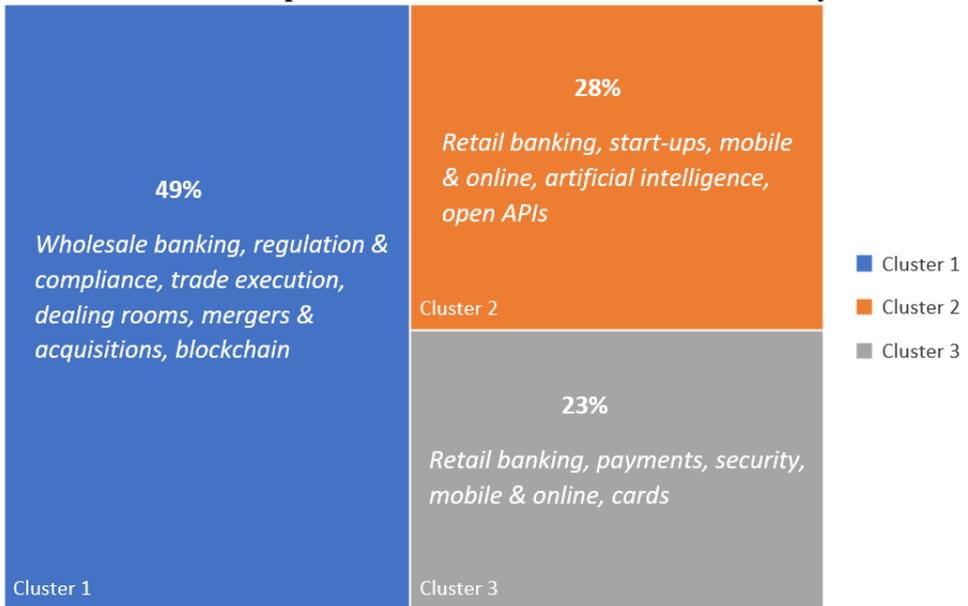
Appendix F1
Top 30 Enterprises by Degree Centrality in 2008, 2015, and 2022

	2008	2015	2022
1	Citi	Visa	Mastercard
2	HSBC	Citi	Citi
3	Barclays Bank	Deutsche Bank	Visa
4	MasterCard	JPMorgan Chase	JPMorgan Chase
5	Deutsche Bank	Barclays Bank	Barclays Bank
6	NYSE	MasterCard	HSBC
7	Credit Suisse	HSBC	NatWest
8	JPMorgan Chase	UBS	FCA
9	Nasdaq OMX Group	Bank of America	Swift
10	Visa	Bank of New York Mellon	Goldman Sachs
11	Refinitiv	BBVA	Lloyds Banking Group
12	Royal Bank of Scotland	Nasdaq OMX Group	BNP Paribas
13	LCH.Clearnet	PayPal	Coinbase
14	London Stock Exchange	Accenture Financial Services	Google
15	Bank of America Merrill Lynch	Credit Suisse	Klarna
16	Bank of America	Royal Bank of Scotland	UBS
17	IHS Markit	American Express	Bank of America
18	Temenos	Goldman Sachs	BNY Mellon
19	Goldman Sachs	Lloyds Banking Group	BIS
20	Lehman Brothers	Toronto Dominion Bank	Wells Fargo
21	BNP Paribas	Morgan Stanley	Gemini
22	Lloyds Banking Group	US Bank	Microsoft
23	FIS Global	Fiserv, Inc.	Robinhood
24	UBS	Royal Bank of Canada (RBC)	US Bank
25	ACI Worldwide	Banco Santander	Amazon Web Services
26	Morgan Stanley	Refinitiv	Deutsche Bank
27	Chi-X	Commerzbank	Monzo
28	Instinet	ING	Starling Bank
29	Swift	Swift	Zero Hash
30	Turquoise	CME Group	NAB

Notes: FCA – Financial Conduct Authority; BIS – Bank for International Settlement; NAB – National Australia Bank

Appendix F2
Top 30 Enterprises by Eigenvector Centrality in 2008, 2015, and 2022

	2008	2015	2022
1	Citi	Citi	Citi
2	HSBC	Deutsche Bank	Mastercard
3	Deutsche Bank	Bank of America	JPMorgan Chase
4	Barclays Bank	Bank of New York Mellon	Wells Fargo
5	Credit Suisse	JPMorgan Chase	BNY Mellon
6	JPMorgan Chase	HSBC	US Bank
7	Royal Bank of Scotland	Barclays Bank	PNC Financial Services Group
8	Goldman Sachs	Morgan Stanley	Truist
9	Bank of America Merrill Lynch	UBS	HSBC
10	IHS Markit	Visa	Swift
11	UBS	Toronto Dominion Bank	Amazon Web Services
12	Bank of America	Goldman Sachs	Federal Reserve Board
13	Morgan Stanley	Société Générale	SETL
14	Lehman Brothers	Royal Bank of Canada (RBC)	Digital Asset Holdings
15	BNP Paribas	Credit Suisse	Barclays Bank
16	NYSE	Royal Bank of Scotland	TD Bank
17	London Stock Exchange	NAB	Bank of America
18	Refinitiv	Commerzbank	Goldman Sachs
19	Chi-X	SEB	NatWest
20	Instinet	MasterCard	Visa
21	MasterCard	Refinitiv	Capital One
22	Visa	US Bank	Lloyds Banking Group
23	LCH.Clearnet	Bloomberg	Google
24	Société Générale	American Express	Morgan Stanley
25	CME Group	PayPal	BNP Paribas
26	Turquoise	BlackRock	UBS
27	Lloyds Banking Group	Standard Chartered Bank	Deutsche Bank
28	ABN Amro	Nasdaq OMX Group	Standard Chartered Bank
29	Tradeweb	BNP Paribas	Early Warning Services
30	HBOS	BBVA	FCA

Notes: NAB – National Australia Bank; FCA – Financial Conduct Authority

Appendix F3
Top 30 Enterprises by Closeness Centrality in 2008, 2015, and 2022

	2008	2015	2022
1	Citi	Deutsche Bank	Mastercard
2	Deutsche Bank	Barclays Bank	Citi
3	HSBC	Citi	JPMorgan Chase
4	Barclays Bank	UBS	Visa
5	JPMorgan Chase	JPMorgan Chase	Barclays Bank
6	Credit Suisse	Visa	NatWest
7	Royal Bank of Scotland	HSBC	Google
8	Refinitiv	Nasdaq OMX Group	Lloyds Banking Group
9	Bank of America	Royal Bank of Scotland	FCA
10	IHS Markit	Bank of America	Amazon Web Services
11	MasterCard	BBVA	Goldman Sachs
12	NYSE	Bank of New York Mellon	Klarna
13	BNP Paribas	Lloyds Banking Group	BNP Paribas
14	Bank of America Merrill Lynch	Credit Suisse	HSBC
15	Morgan Stanley	BNP Paribas	Swift
16	UBS	Morgan Stanley	Wells Fargo
17	Lehman Brothers	MasterCard	Payment Systems Regulator
18	LCH.Clearnet	Standard Chartered Bank	Standard Chartered Bank
19	Goldman Sachs	PayPal	US Bank
20	London Stock Exchange	Goldman Sachs	Deutsche Bank
21	Visa	Banco Santander	BNY Mellon
22	CME Group	Refinitiv	UBS
23	Société Générale	Accenture Financial Services	Morgan Stanley
24	ING	Fiserv, Inc.	NAB
25	SAP	Rabobank	Starling Bank
26	Nasdaq OMX Group	Swift	MasterCard
27	Swift	CME Group	PNC Financial Services Group
28	Chi-X	Capital One	Truist
29	Instinet	American Express	Capital One
30	IBM Financial Services	Nationwide	CMA

Notes: FCA – Financial Conduct Authority; NAB – National Australia Bank

Appendix F4
Top 30 Enterprises by Betweenness Centrality in 2008, 2015, and 2022

	2008	2015	2022
1	Citi	Visa	Mastercard
2	MasterCard	Deutsche Bank	Visa
3	HSBC	Barclays Bank	Citi
4	Nasdaq OMX Group	Citi	JPMorgan Chase
5	Refinitiv	JPMorgan Chase	Barclays Bank
6	NYSE	UBS	NatWest
7	Deutsche Bank	Nasdaq OMX Group	Lloyds Banking Group
8	Visa	Swift	Microsoft
9	Barclays Bank	MasterCard	Swift
10	IBM Financial Services	Accenture Financial Services	Google
11	Credit Suisse	Banco Santander	HSBC
12	JPMorgan Chase	BBVA	FCA
13	Temenos	HSBC	Klarna
14	FIS Global	PayPal	BNP Paribas
15	SAP	Euroclear	UBS
16	IHS Markit	ECB	NAB
17	BNP Paribas	ING	Goldman Sachs
18	LCH.Clearnet	Fiserv, Inc.	BIS
19	Swift	Ripple	Deutsche Bank
20	Bank of America	ANZ Banking Group	Monzo
21	Bank of America Merrill Lynch	Lloyds Banking Group	MasterCard
22	PayPal	Royal Bank of Scotland	Money20/20
23	London Stock Exchange	Six Group AG	Starling Bank
24	Microsoft Financial Services	EBA Clearing	Coinbase
25	Lehman Brothers	CME Group	Amazon
26	CME Group	Google	Nexi
27	Société Générale	IHS Markit	FTX
28	FCA	Bank of America	ING
29	Royal Bank of Scotland	Refinitiv	Binance
30	Nordea	Goldman Sachs	Revolut

Notes: ECB - European Central Bank; FCA – Financial Conduct Authority; BIS – Bank for International Settlement; NAB – National Australia Bank

Appendix G
Most Frequent FinTech News Keywords by Year (2008–2022)

year	keywords
2008	mergers & acquisitions, dealing rooms, core banking systems, reporting/compliance, research/analysis, trade execution, futures & options, outsourcing, cards, automated teller machines & network services
2009	cards, dealing rooms, trade execution, post-trade & ops, mergers & acquisitions, reporting/compliance, card fraud, electronic bill presentment & payment, research/analysis, phishing
2010	dealing rooms, foreign exchange, mergers & acquisitions, cards, EFTPOS, legal, post-trade & ops, financial messaging, fix, reporting/compliance
2011	cards, automated teller machines & network services, mergers & acquisitions, e-commerce, legal, research/analysis, social media, EFTPOS, dealing rooms, trade execution
2012	cards, card fraud, cheque imaging, legal, social media, mobile & online banking, outsourcing, dealing rooms, post-trade & ops, financial messaging
2013	cards, mobile & online banking, automated teller machines & network services, EFTPOS, accounting, legal, mergers & acquisitions, money laundering, research/analysis, trade execution
2014	innovation, mobile & online banking, post-trade & ops, instant messaging, reporting/compliance, blockchain, money laundering, cards, legal, EFTPOS
2015	mobile & online banking, social media, automated teller machines & network services, marketing, personal finance, blockchain, cards, legal, e-commerce, EFTPOS
2016	innovation, mobile & online banking, post-trade & ops, trade execution, blockchain, transaction banking, cards, automated teller machines & network services, electronic bill presentment & payment, personal finance
2017	innovation, mergers & acquisitions, portfolio management, transaction banking, money laundering, operational risk, cards, mobile & online banking, e-commerce, non-bank competitors
2018	mobile & online banking, mergers & acquisitions, trade execution, post-trade & ops, mifid, reporting/compliance, cards, innovation, EFTPOS, biometrics
2019	mobile & online banking, mergers & acquisitions, non-bank competitors, artificial intelligence, innovation, blockchain, trade execution, post-trade & ops, cards, biometrics
2020	mobile & online banking, cards, e-commerce, open APIs, innovation, biometrics, mergers & acquisitions, automated teller machines & network services, trade execution, artificial intelligence
2021	mergers & acquisitions, Brexit, cards, EFTPOS, artificial intelligence, chatbot, mobile & online banking, e-commerce, legal, BNPL
2022	open banking, mergers & acquisitions, mobile & online banking, blockchain, cards, EFTPOS, legal, BNPL, financial messaging, artificial intelligence