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Assessing global interest in decentralized finance, embedded finance, open finance, ocean finance and sustainable finance

Peterson K. Ozili

Abstract

This paper analyzes global interest in internet information about decentralized finance (DeFi), embedded finance (EmFi), open finance (OpFi), ocean finance (OcFi) and sustainable finance (SuFi) and the relationship among them. The findings reveal that global interest in internet information about embedded finance (EmFi) was more popular in Asian and European countries. Global web search for internet information about OcFi decreased during the financial crisis while global web search for internet information about OpFi and EmFi increased during financial crisis years. Global web search for internet information about DeFi, SuFi and EmFi increased during the pandemic years. There is a significant positive correlation between global interest in decentralized finance, embedded finance, ocean finance and sustainable finance information. Also, there is a significant negative correlation between global interest in embedded finance information and global interest in open finance information. The regression coefficient matrix shows that global interest in information about open finance, embedded finance, ocean finance, decentralized finance and sustainable finance are significantly related.

Keywords: information technology, internet, decentralized finance, open finance, embedded finance, ocean finance, sustainable finance.

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1. Introduction

Modern financial innovations come in many forms such as sustainable finance (SuFi), social finance (SoFi), decentralized finance (DeFi), embedded finance (EmFi), open finance (OpFi), ocean finance (OcFi), circular finance (CiFi), blockchain finance (BoFi) and so on. They exist mainly to increase access to finance for specific activities or projects. Before adopting a new financial innovation, people and organizations will search for information about the new financial innovation. They will search for information on the internet to gain substantial knowledge or information about the new financial innovation and how it works. They can also conduct research about new financial innovations using internet information. The outcome of their research can help them reach a decision on whether to adopt or reject the innovation. This means that internet information about a new financial innovation can play an important role in determining whether a new financial innovation will be adopted or rejected.

The objective of this paper is to analyse global interest in internet information about decentralized finance, embedded finance, open finance, ocean finance and sustainable finance, and the interrelationship among them. The paper used global web search data from Google Trends database to measure global interest in internet information about DeFi, EmFi, OpFi, SuFi and OcFi. DeFi or decentralized finance refers to an ecosystem of financial applications that are developed on top of blockchain and distributed ledger systems (Popescu, 2020). DeFi uses decentralized networks and open source software to create or transform old financial products into trustworthy and transparent protocols that run without intermediaries (Popescu, 2020). DeFi uses smart contracts to create protocols that replicate existing financial services in a more open, interoperable and transparent way (Schär, 2021).

Embedded finance (EmFi) is the integration of financial services into the customer offerings of non-financial institutions (Kore Fusion, 2021). Embedded finance allows the delivery of financial services directly into the websites, mobile applications and business processes of non-financial organizations (Oracle, 2021). Embedded finance allows financial companies to incorporate financial services into their payments journey. Embedded financial services are offered to customers through easy-to-use application programming interface (API) integrations that are modular by design and allow brands to easily incorporate them into their existing payments technology stack (PPS, 2021). Open finance allows data sharing and third-party access to a wide range of financial services and products (FCA, 2019). The aim of open finance is to open up more data about people's finances in order to give consumers greater control over their data and give consumers the power to make better financial decisions (Finlab, 2021). Open finance provides a framework that allows consumers and enterprises to access and share financial data with third-party providers who can use the shared data to develop innovative products and services with consent (Mothibi et al, 2020).

Ocean finance refers to all financial services and financial instruments that are used to raise funds that will be channeled towards improving the health of marine ecosystems or to address existing problems in marine or ocean life (Sumaila et al, 2021). Sustainable finance refers to financial product and service offerings that take into account the pertinent environmental, social and governance (ESG) factors when making financing and investment decisions in the financial sector (Schumacher et al, 2020; Ozili, 2022c).

Many studies have examined the effect of financial innovation on welfare (e.g. Allen, 2012; Mullineux, 2010; Farzin et al, 2021); the effect of financial innovation on the economy (e.g. Johnson and Kwak, 2012; Laeven et al, 2015; Thottoli, 2022); the effect of financial innovation on banking and financial stability (e.g. Norden et al, 2014; Kim et al, 2013); the different types of financial innovation (e.g. Schindler, 2017; Zavolokina et al, 2016) and the regulation of innovative financial products and services (e.g. Lumpkin, 2010; Kim et al, 2013; Ozili, 2022a). Yet, existing studies have not analyzed global interest in information about specific financial innovations such as global interest in decentralized finance, embedded finance, open finance, ocean finance and sustainable finance, and the interrelationship among them. None of the existing studies have explored the relationship between DeFi, EmFi, OpFi, OcFi and SuFi using 'interest over time' data. To the best of my knowledge, this is the first paper to analyse the association between interest in DeFi, EmFi, OpFi, OcFi and SuFi information. Thus, this study addresses an important knowledge gap in the literature by exploring people's interest in internet information about DeFi, EmFi, OpFi, OcFi and SuFi. Given this background, the present study investigates the association between global interest in internet information about decentralized finance, embedded finance, open finance, ocean finance and sustainable finance.

This study contributes to the literature in two ways: first, the study contributes to the literature that examines the factors that give rise to new financial innovations. The present study shows that interest in information about a specific financial innovation spurs interest in other financial innovations. Second, this study contributes to the literature that examines the determinants of the adoption of financial innovation. This study contributes to this literature by showing that interest in internet information about DeFi, EmFi, OpFi, OcFi and SuFi is a determinant of whether people will adopt these financial innovations.

The rest of the paper is organized as follows. Section 2 provides the theory and literature review. Section 3 presents the research methodology. Section 4 reports the empirical results. Finally, section 5 concludes the paper.

2. Literature Review

2.1. Diffusion of innovation theory

The diffusion of innovation theory developed by E.M. Rogers in 1962 provides a good explanation on how innovation spreads within a population from introduction of the innovation to widespread adoption of the innovation. The theory showed that innovations spread from introduction of the innovation to early adopters, early majority adopters, late majority adopters and to the laggards. Rogers (2010) identified five elements that influence the spread of a new innovation. The five elements are as follows: the innovation itself, the adopters, the communication channels, time and a social system. By communication channels, Rogers refers to the way in which innovations are communicated to different parts of society. Rogers argued that the way in which innovations are communicated to different parts of society is an important factor influencing the early adoption or late adoption of innovations. In this paper, the internet is considered to be main communication channel through which people learn about specific innovations such as DeFi, EmFi, OpFi, OcFi and SuFi. This study considered web search for internet information about specific innovations to be a crucial determinant of people's growing interest or declining interest in specific innovations. I then argue that the early adopters of decentralized finance, embedded finance, open finance, ocean finance and sustainable finance innovations are people in society who searched for internet information about these innovations at an early stage. Doing so at an early stage allowed them to understand the benefits and risks of these innovations thereby leading to greater interest in these innovations, and it helped them to reach a decision to embrace decentralized finance, embedded finance, open finance, sustainable finance and ocean finance at an early stage. In contrast, late adopters did not use the internet to search for these things; rather, they adopted these innovations because other people have already adopted it.

2.2. Embedded finance literature

Existing studies on embedded finance in the literature are practitioner white papers rather than academic papers. For example, Plaid and Accenture (2021) explored the huge opportunity for embedded finance in the financial sector. They showed that embedded finance can improve customer experience and unlock a huge market opportunity. They also showed that embedded finance has the potential to generate US\$230billion in net new revenue by 2025. Plaid and Accenture (2021) suggest four ways through which embedded finance can change how financial and nonfinancial companies do business in an era of embedded financial services. They suggest the need to (i) re-arrange relationships between financial providers and businesses; (ii) create new revenue streams for financial and non-financial companies; (iii) create new forms of competition in financial services and other industries; and (iv) launch new partnerships among financial providers on behalf of businesses and providing them with the know-how to benefit

from embedded finance without hiring teams of software developers and compliance experts (Plaid and Accenture, 2021). Compton (2021) showed that large-scale embedded finance can open the door to major innovation in financial services and can generate revenue of over US\$140.8 billion by 2025 only if embedded finance is (i) driven by technology, (ii) offered and co-developed with third-party companies, and (iii) leads to a shift from a business to customer (B2C) model to a business to business (B2B) model for Fintech. Compton (2021) further argued that being prepared for embedded finance disruption and being open to the opportunities and partnerships that embedded finance presents will be vital because of the opportunities it presents for the Fintech ecosystem, the financial services industry and for global clients.

Torrance (2020) argued that by embedding banking and insurance functionality into the business of non-financial services, embedded finance allows a business or merchant to integrate low-cost innovative financial services into customer experiences. He argued that there are three key issues that need to be addressed for a successful transformation to embedded finance. The issues are (i) leadership understanding and commitment, (ii) organisational structure, operating model and skills, and (iii) technical capability. In another report, Kore Fusion (2021) showed that embedded finance can transform finance and create US\$ 7 trillion of market value by 2030. They showed that the embedded finance transformation will be driven by the shift to e-commerce and the use of APIs and banking as a service (BaaS) providers. They conclude that incumbent players and Fintech providers need to position themselves to partake of the embedded finance opportunity and develop their own embedded finance strategy. Teboul and Anastasiou (2021) showed that operationalizing embedded financial services will require deep expertise to manage regulatory, legal and compliance matters; and it demands significant technology investment, specialized skills to operate the services at scale and will also require high cost for businesses that want to offer embedded financial services to their customers.

2.3. Decentralized finance (DeFi) literature

Several studies in the literature such as Ozcan (2021), Katona (2021), Chohan (2021), Ozili (2022b) and Schär (2021) showed that there is widespread interest in DeFi because of its potential to eliminate traditional financial intermediaries, improve access to financial services, increase financial inclusion, increase transaction speed, improve flexibility in smart contracts, increase privacy and transparency, enhance security, increase trust and increase efficiency in the form of reduction in overhead costs for banks. Yavin and Reardon (2021) showed that decentralized finance (DeFi) can revolutionize modern finance by making banking more accessible and more flexible in society. Yavin and Reardon (2021) then advise banks to use DeFi solutions to improve their own banking product and services offerings. Meegan and Koens (2010) argued that decentralized finance is a new paradigm which allows decentralized financial services to be offered on the blockchain. They showed that although DeFi has numerous benefits, it also poses serious risks. Meegan and Koens (2010) opposed the idea of replacing centralized financial

services (CeFi) with decentralised financial services (DeFi). Rather, they argued that there is a need for DeFi and CeFi to cooperate and coexist in the same financial system so that customers can enjoy the benefits of the two systems.

Some studies have assessed the challenges of DeFi. For instance, Zetzsche et al (2020) criticized decentralized finance and argued that decentralized finance has the potential to undermine traditional forms of accountability and erode the effectiveness of traditional financial regulation and enforcement. Zetzsche et al (2020) stressed the need for the regulation of decentralized finance through 'embedded regulation' which allows regulation to be in-built in the design of decentralized finance. Chen and Bellavitis (2020) showed that decentralized finance may reshape the structure of modern finance and create a new landscape for entrepreneurship and innovation and could give rise to decentralized business models. Chen and Bellavitis (2020) showed that although decentralized finance could make the financial system more decentralized, decentralized finance still has to overcome a number of challenges to achieve its full potential. Chohan (2021) showed that decentralized finance (DeFi) prioritizes disintermediation and decentralization to empower individuals along crypto-anarchist principles. Chohan (2021) further showed that DeFi is often mired in many difficulties including market manipulation, distortionary incentives, excess short-termism, Ponzi schemes and money-laundering challenges that significantly hinder the widespread adoption of decentralized finance.

Schär (2021) showed that DeFi uses smart contracts to create protocols that replicate existing financial services in a more open, interoperable and transparent way. However, Schär (2021) stressed that DeFi is still a small niche market with specific risks even though it has the potential to improve efficiency, transparency, accessibility and composability. Katona (2021) argued that although decentralized finance has the potential to provide financial services with an open, transparent and robust infrastructure, a great deal of effort is required for the development of the DeFi sector and the effective management of emerging risks associated with DeFi. Ozcan (2021) showed that although DeFi has promising benefits, DeFi markets in their current state are not technologically able to provide financial services on a global scale and at the scale that centralized finance (CeFi) provides. Ozcan (2021) then called for improved DeFi technology and sound regulation to increase DeFi acceptance. Johnson (2020) argued that although there are many crypto-enthusiasts who support and advocate for DeFi, many crypto trading platforms often turn to traditional financial service firms to receive help and support when their own crypto trading platforms fail, thereby showing that these DeFi platforms have not lived up to their promise of decentralizing financial services since they still seek help from traditional financial institutions.

2.4. Open finance literature

Existing studies on open finance in the literature are mostly practitioner white papers rather than academic papers. For instance, Equinix (2020) argued that open finance can lead to a shift in the entire banking process and can usher in an era of open collaboration across the digital ecosystem, and it can also lead to an increase in the demand for exchange of private data between businesses. Khan and Eroglu (2020) argued that open finance creates an umbrella that takes products and services and connects them across a shared framework. They further argued that open finance can eliminate the data fragmentation problem in the traditional financial system by providing a secure and efficient means for customers to allow businesses to share and use customer data across a common framework and this will lead to increase in new competitors and will encourage innovation (Khan and Eroglu, 2020). Mothibi, Lazaridis and Rahulani (2020) showed that open finance is enabled by specific technologies such as open API, cloud computing, big data and artificial intelligence. Many applications of open finance can be found in payments, account aggregation, insurance, alternative lending and in financial management. Mothibi et al (2020) also argued that the three main parties involved in an open finance ecosystem are (i) existing financial institutions that collect and store customer data, (ii) the third parties that collect customer data from financial institutions using APIs to offer value-added services to customers and (iii) the customers whose information are collected and stored. In their research analysis, they showed that screen scraping and Application Programming Interface (API) technologies are the main technologies that are used to facilitate open finance. However, they stressed that issues such as data privacy issues and cybersecurity issues will remain in the absence of effective and meaningful regulation.

Hope (2021) showed that open banking will transform into open finance, and open finance will become integrated into digital ecosystems or platforms thereby blurring industry boundaries towards creating an open data economy. This means that banks need to re-think their business models in order to provide compelling new propositions to their customers in order to stay relevant in an industry served by a complex web of players in the open data ecosystem. Mercer and Hallas (2021) showed that although the UK has adopted open banking, some identified issues in the UK open finance model are (i) the lack of collaboration between customers, regulators and third parties, (ii) the imposition of a 90-day re-authentication rule, and (iii) the lack of regulation for digital data sharing right. They then suggest some steps to address these issues. They suggest (i) the creation of a new data sharing right legislation, (ii) the removal of the 90-day re-authentication rule, (iii) the introduction of technologically-neutral regulation or principles-based smart regulation to govern the move towards open finance and (iv) the creation of a better governance architecture that incorporates better collaboration between regulators, financial institutions, third-party agents and customers. Woodhurst (2020) argued that the number of individuals and small businesses that have used open banking products or services has more than

doubled in 2020. Woodhurst (2020) then suggests ways that the finance industry can lay the foundation for open finance. Woodhurst (2020) suggests that there should be (i) a consistent approach to contextualised data sharing, (ii) greater focus should be placed on value exchange to drive awareness and consumer education, (iii) financial institutions should embrace further regulation as an opportunity and business enabler, (iv) financial institutions should appreciate the compelling business case for change and (v) financial institutions should embrace digitization as a step to open finance. Arner et al (2021) argued that the future of data sharing under an open finance framework can lead to two extremes: the first case is a situation where data will be controlled by a small number of massive firms and governments who will use it for profit, suppression and control purposes while the second case is a situation where data will be under the control of individuals which should support a more open and innovative economy and society.

2.5. Ocean finance

Walsh (2018) defined ocean finance as effective investment of financial capital to produce sustained ocean governance. Walsh (2018) suggested four actions that are necessary for effective ocean finance. They are (i) generate public and private financial capital through traditional and innovative finance mechanisms to create a diversified portfolio of revenue that supports ocean health; (ii) invest financial capital effectively, efficiently and strategically to achieve measurable ocean outcomes and sustained ocean governance; (iii) account for how financial capital is deployed against performance benchmarks and account for values of marine ecosystem services through time; and (iv) align public and private economic incentives with long-term ocean health.

Regarding the aim of ocean finance, the European commission states that the aim of ocean finance is to build an international coalition of financial institutions that endorse the sustainable blue economy finance principles on a voluntary basis, applying the principles to their investment decisions thereby showing their support for healthy oceans and for the development of a sustainable blue economy. Pereira and Nogueira (2021) argued that the transition to the blue (or ocean) economy requires funding contributions which is known as ocean finance. They also argued that despite global efforts to develop principles to motivate investors to support projects suitable for a blue economy perspective, the ocean finance project still has a long journey towards establishing a relevant ocean finance arrangement towards a sustainable use of the oceans. UNDP (2022) argued that financial institutions can play a critical role in embedding social equity across ocean-linked sectors through their investment, financing and underwriting decisions.

Wabnitz and Blasiak (2019) argued that a major challenge for ocean financing is the difficulty in securing adequate financial resources to achieve the sustainable ocean economy goals, and it will be difficult to obtain a funding mechanism that go beyond traditional official development

assistance and philanthropy. Sumaila et al (2021) identified some barriers to financing a sustainable ocean economy. The barriers are (i) the gaps in understanding how the ocean economy contributes to the wider global economy; (ii) the lack of universally adopted definitions, standards and taxonomy on what counts as a sustainable ocean economy investment and (iii) market distortions. They argued that each of these barriers inhibit financing for a sustainable ocean economy and jeopardizes the future of biodiversity and ocean-based economic opportunities. Shiiba et al (2022) propose a solution to these challenges which is to develop connections between all stakeholders to illustrate potential incentives for increasing private investment and public donations. This can be achieved through a regulatory-driven financing mechanism that incorporates the core concepts of blue finance in the context of marine governance both at the international and domestic levels. Notwithstanding, Thiele (2020) argued that convincing private sector investors and multilateral financing that blue infrastructure finance is not only possible and desirable but that it is both feasible and financially attractive is critical to achieve a just transition to sustainability. Rustomjee (2016) showed that small developing states have had limited success and are at the very earliest stages of mobilizing and securing finance and investment for the blue economy with most resources typically confined to established areas rather than new blue growth sectors. The author also points out that there are many challenges in scaling up finance and attracting investments in a wider range of blue growth sectors in small states. The author then argued that there is a need to (i) develop an enabling environment to attract investment, (ii) improve information sharing among small states and (iii) gain the support of international development partners and new partnerships to leverage blue investments, in order to overcome these challenges.”

2.6. Sustainable finance

Schumacher et al (2020) defined sustainable finance as financial product and service offerings that take into account the pertinent environmental, social and governance (ESG) factors when making financing and investment decisions in the financial sector. Schoenmaker (2017b) argued that traditional finance focuses solely on financial return and risk while sustainable finance considers financial, social and environmental returns and is aimed at long-term value creation for the wider community. He argued that the major obstacles to sustainable finance are short-termism and insufficient private efforts. Fatemi and Fooladi (2013) argued that the traditional finance approach to shareholder wealth maximization is no longer a valid guide to the creation of sustainable wealth because of its emphasis on short-term results which has had the unintended consequence of forcing many firms to externalize their social and environmental costs. They also argued that an unwavering faith in markets' ability to efficiently uncover long-term value implications of short-term results has created many unacceptable outcomes.

Sandberg (2018) argued that financial institutions should contribute to sustainable financing as part of their social responsibility to society. Kemfert and Schmalz (2019) suggest the need to

develop a framework that encourages private financial market players towards sustainability. Pimentel and Ramírez (2021) emphasized the need to create concrete laws and regulations that incentivize actors in the financial markets to redirect funds from non-sustainable investments to sustainable alternatives. Fullwiler (2016) showed that the four important trends contributing to the growth of sustainable finance are blended-value investing; recognition that sustainability factors can be related to systematic risk; financial innovation to increase sustainability and building infrastructure for sustainable finance. Hong et al (2021) state that the financial sector is being pressured to help keep global temperatures within 1.5 degree Celsius above pre-industrial levels. They show that governments and activists are pressuring financial institutions to ensure that a fraction of their portfolios are restricted to hold firms that can meet net-zero emissions targets by 2050. Schoenmaker (2017a) showed that financial institutions have started to avoid unsustainable companies from a risk perspective, and the frontrunners of sustainable financing are now increasingly investing in sustainable companies and projects to create long-term value for the wider community. However, the major obstacles to sustainable finance are short-termism and insufficient private efforts.

Migliorelli (2021) observed that the sustainable finance landscape is dominated by an overabundance of heterogeneous concepts, definitions, industry and policy standards. The author argued that such heterogeneity may hinder the smooth development of the conceptual thinking underpinning sustainable finance and it could give rise to specific risks that may harm the credibility of the sustainable finance agenda. These risks include green and sustainable washing, the rebranding of financial flows, and the disordered adjustment in the cost of capital spreads between industries. Ziolo et al (2021) examined the link between sustainable finance and SDGs. They analysed European countries in the OECD, and argued that the sustainable finance model plays a fundamental role in implementing SDGs and ensuring that social and environmental sustainability are reflected in SDGs. They find that the more sustainable the finance model, the better the achievement of SDGs in the group of analysed countries. They also found a strong link between sustainable finance model and social sustainability (SDG 1, 3, 4, 5, 10, 16); environmental sustainability (SDG 11, 12, 13, 15) and economic sustainability (SDG 8, 9, 17). Meanwhile, Ozili (2022c) formulates theories of sustainable finance, namely, the priority theory of sustainable finance, the resource theory of sustainable finance, the peer emulation theory of sustainable finance, the life span theory of sustainable finance, the positive signaling theory of sustainable finance, and the system disruption theory of sustainable finance. Ozili (2022c) argue that these theories offer believable explanations for the behaviour and actions of economic agents towards sustainable finance.

3. Research Methodology

3.1. The data

Monthly data were extracted from Google Trends database. Data were extracted for five variables, namely, 'interest in decentralized finance' data, the 'interest in embedded finance' data, 'interest in sustainable finance' data, 'interest in ocean finance' and the 'interest in open finance' data. These five variables were selected because recent studies show that decentralized finance, embedded finance, open finance, ocean finance and sustainable finance are the future of finance and are also considered to be the main disruptors of modern finance (see, for example, Woodhurst (2020), Arner et al (2021), Schär (2021), Ozcan (2021), Compton (2021) and Torrance (2020)). The sample period is from January 2004 to January 2022 while the country coverage is global.

The data obtained from Google Trends database measures interest over time (or the popularity) of specific web-search keywords on the internet. The data reflect the number of times people searched for specific keywords in a location or a time period. To obtain the data, I simply query the Google Trends database by inserting the keywords 'decentralized finance' into the search box in the Google Trends database. The resulting data are what I refer to as 'interest in decentralized finance' data. This procedure is repeated for the 'embedded finance', 'open finance', 'ocean finance' and 'sustainable finance' keywords. The data output from the database are numbers (or popularity count) ranging from 0 to 100. These numbers represent interest in a keyword relative to the highest point on the scale for the given location, region and time. The numbers capture the relative popularity of a keyword. A count of less than 50 indicates that interest in the keyword was relatively low. A count of 50 means that interest in the keyword is half as popular. A count of 100 means that interest in the keyword was highly popular and reached the peak popularity for the term. A score of 0 means there was not enough data for the term.

4. Results

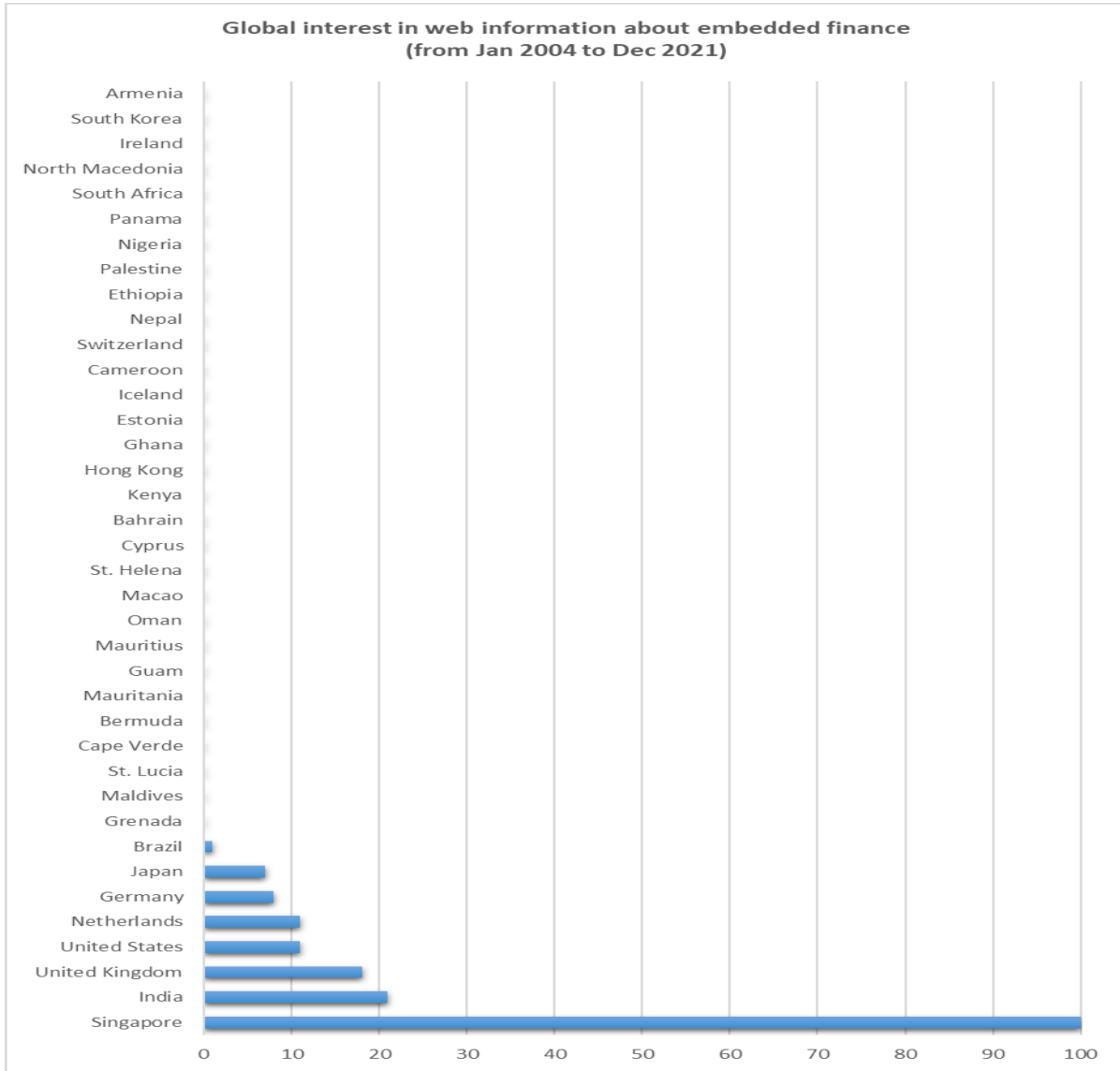
4.1. Country interest over time: graphical analysis

4.1.1. Interest in embedded finance (EmFi)

Figure 1 presents the data for global web search for information about embedded finance (EmFi). Figure 1 shows that some Asian and European countries recorded the highest web search for information about embedded finance during the period. The countries include Singapore, India, United Kingdom, the United States, Germany and Japan. Interest in web information about embedded finance exceeded the 50-point mark in Singapore. This indicates that embedded

finance was relatively more popular in Singapore during the period. This implies that web search for information about embedded finance was greater in Singapore than in any other country in the world during the period. The high interest in internet information about EmFi in Singapore was due to increase in the demand for embedded financial services in Singapore. Singapore has one of the fastest growing markets for embedded financial services in the world. As a result, a lot of people in Singapore are seeking to gain more online information about embedded financial services. People want to learn about how embedded financial services can improve their lives and how it can help to grow their business. In contrast, there is average interest in internet information about EmFi in the United States, the United Kingdom and Germany because people in these countries have easy access to offline information about EmFi and this information can be found in physical workshops, seminars and short courses about embedded finance which are often cheap and affordable in these countries. Since people in these countries can easily access offline information about embedded finance, there is not much incentive for people in these countries to rely heavily on the internet to gain information about embedded finance. Meanwhile, interest in embedded finance is very low in Brazil. The reason for this is the general lack of interest in embedded finance among the population.

Figure 1: Global interest in web information about embedded finance
(from January 2004 to December 2021)



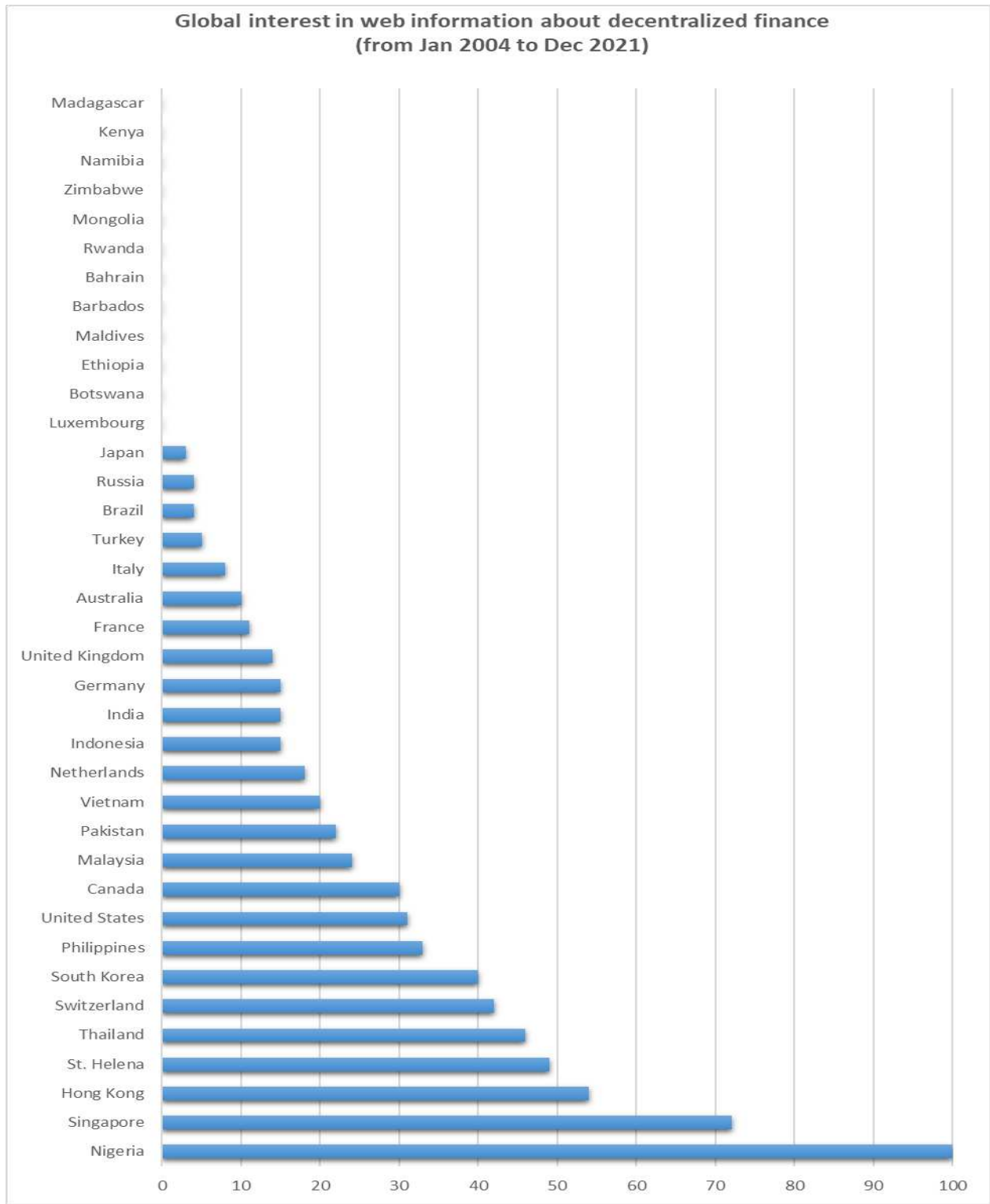
(Source: Google trends)

4.1.2. Interest in decentralized finance (DeFi)

Figure 2 presents the data for global web search for information about decentralized finance (DeFi). Figure 2 shows that global interest in web information about decentralized finance exceeded the 50-point mark in St Helena, Singapore, Hong Kong and Nigeria. Interest in decentralized finance was relatively more popular in Nigeria during the period. This implies that web search for information about decentralized finance was greater in Nigeria than in any other

country in the world during the period. The high interest in internet information about DeFi in developing countries, such as Thailand, Philippines, St Helena and Nigeria, is due to the growing need to gain more information about DeFi-enabled blockchain financial innovations such as cryptocurrency, bitcoins and stablecoins. A lot of people in these developing countries want to hold their wealth in cryptocurrencies – mostly as an investment asset rather than as a currency – to mitigate the decline in their personal wealth caused by the decline in the value of fiat paper currency. As a result, people in these developing countries are seeking more information about cryptocurrencies and related DeFi-enabled financial innovations to help them preserve their wealth especially during economic crisis. In the case of developed countries like the United States, there is average interest in internet information about DeFi because information about DeFi is easily available offline. There are many physical workshops, seminars and short courses about decentralized finance which are cheap and affordable. People in these countries can easily access offline information about DeFi, and this partly explains why interest in internet information about DeFi is not very strong in developed countries such as the United States. In contrast, people in many developing countries cannot easily access offline information about DeFi, therefore, they have to rely mostly on the internet to gain information about decentralized finance. This explains the reason for the high interest in internet information about DeFi in some developing countries. However, interest in DeFi is very low in some countries such as Brazil, Russia and Japan as shown in figure 2. The reason for this is the general lack of interest in decentralized finance among the population due to trust in the existing centralized financial system which has its roots in centralized finance (CeFi).

Figure 2. Global interest in web information about decentralized finance
(from January 2004 to December 2021)

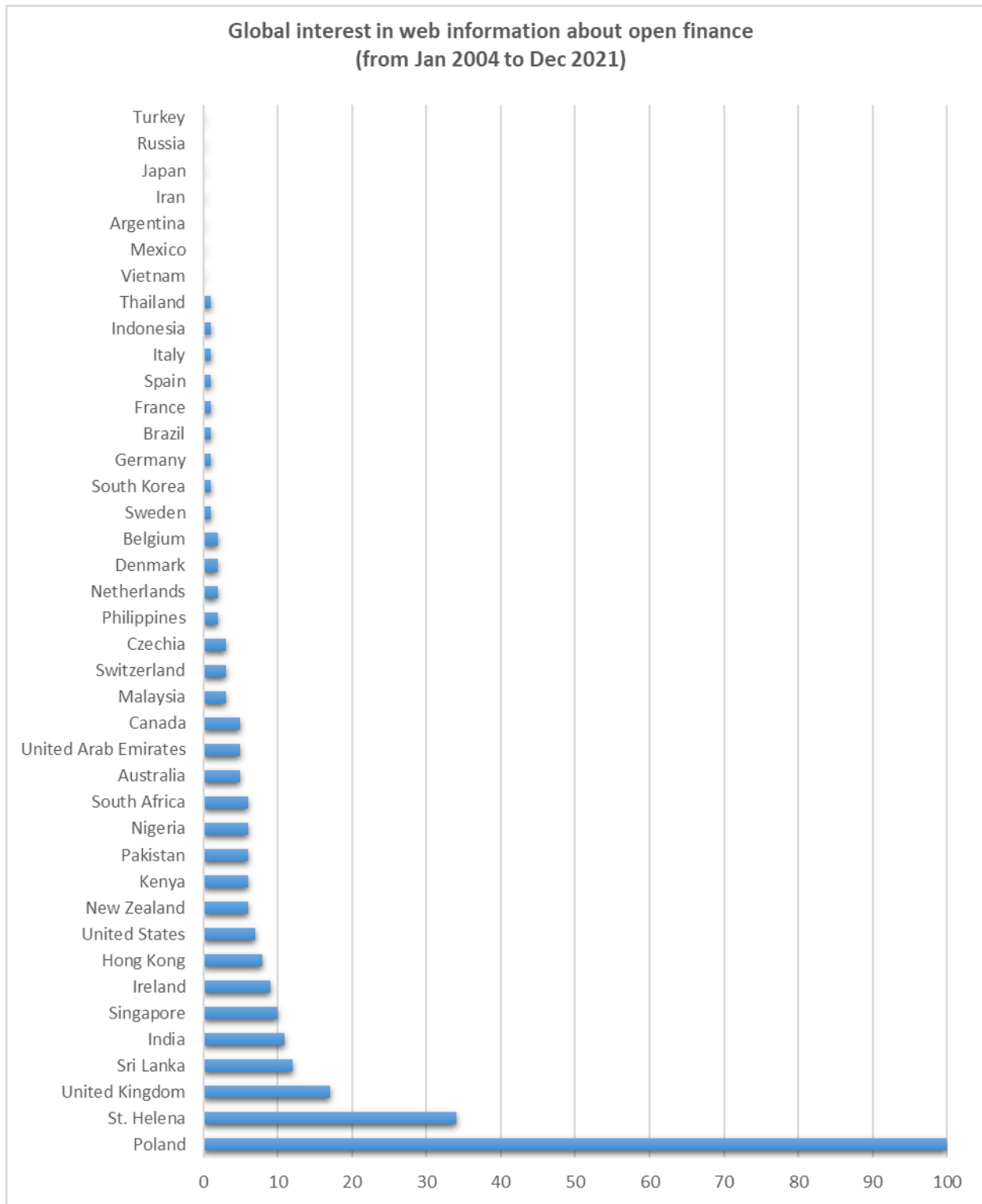


(Source: Google trends)

4.1.3. Interest in Open Finance (OpFi)

Figure 3 presents the data for global web search for information about open finance (OpFi). Figure 3 shows that interest in web information about open finance exceeded the 50-point mark in Poland. This implies that web search for information about open finance was greater in Poland than in any other country in the world during the period. Other countries that recorded some level of interest in open finance are Hong Kong, Singapore, Sri Lanka, United Kingdom and St Helena. The high interest in internet or web information about OpFi in Poland, St. Helena and the United Kingdom is due to increase in the demand for open financial services in these countries. For instance, the UK has a thriving open finance industry where APIs are used to access financial services or banking services remotely. As a result, a lot of people in the UK and Poland are seeking to gain more online information about open finance and open banking to learn about how open finance, or open banking, can improve their lives and how it can help to grow their business. In contrast, there is low interest in internet information about OpFi in countries such as South Korea and Israel due to a general lack of interest in open finance among the population in these countries. There is also zero-interest in internet information about OpFi in countries like Turkey, Russia and Japan.

Figure 3. Global interest in web information about open finance (OpFi)
(from January 2004 to December 2021)

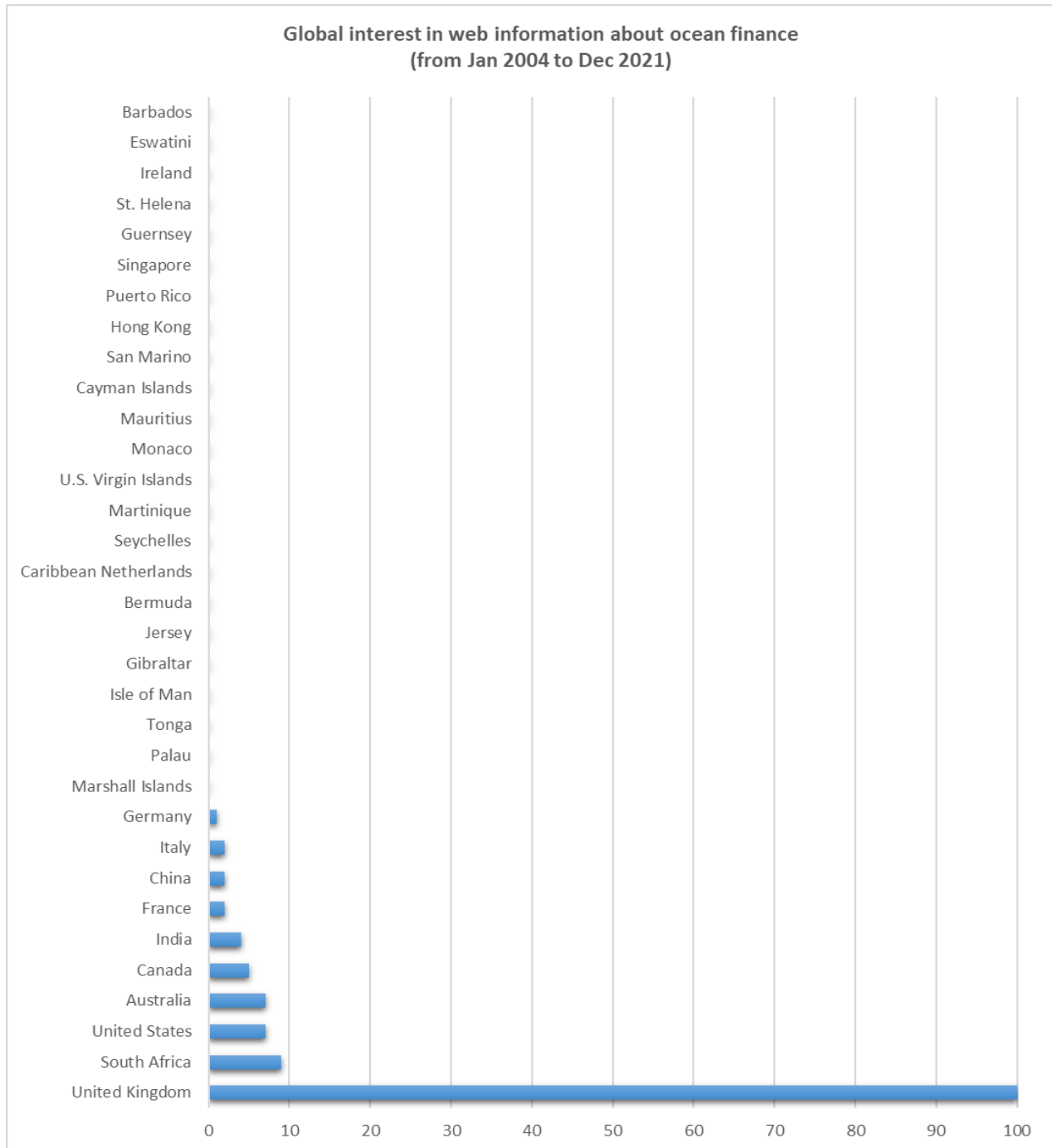


(Source: Google trends)

4.1.4. Interest in Ocean Finance (OcFi)

Figure 4 presents the data for global web search for information about ocean finance (SuFi). Figure 4 shows that interest in web information about ocean finance exceeded the 50-point mark only in the United Kingdom. This implies that web search for information about ocean finance was greater in the United Kingdom than in any other country in the world during the period. Other countries that recorded some level of interest in ocean finance are South Africa, the United States and Australia. The high interest in internet information about OcFi in the United Kingdom is due to the growing interest on the need to protect ocean life in the United Kingdom. In the last decade, the United Kingdom launched a campaign to protect ocean life by ensuring the reduction in plastic waste in the ocean, avoiding ocean-harming products and by voting on ocean issues. In contrast, there is zero-interest in ocean finance in many countries as shown in figure 4. The low interest is due to a general lack of interest in protecting and preserving ocean life in these countries.

Figure 4: Global interest in web information about ocean finance (OcFi)
(from January 2004 to December 2021)

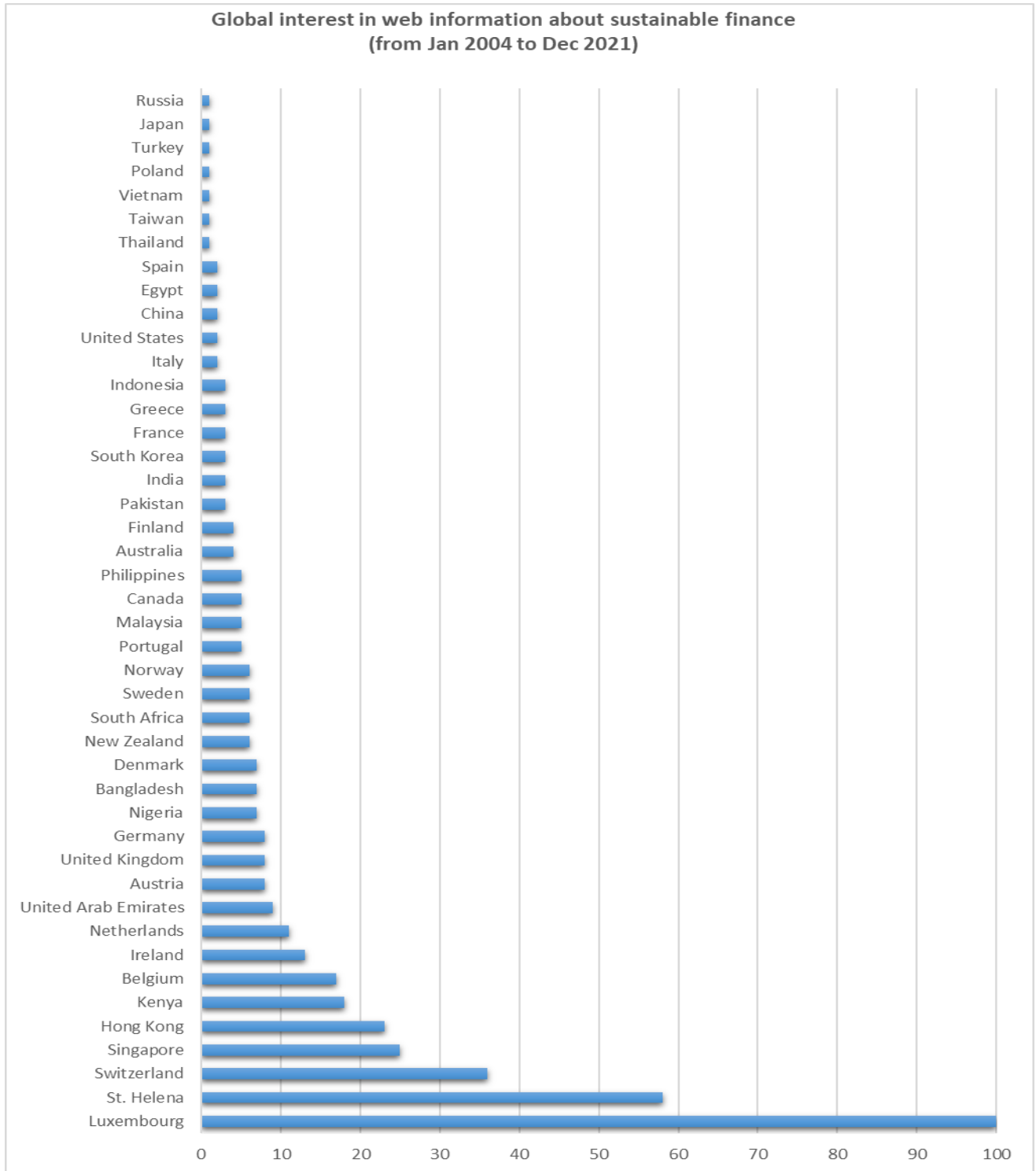


(Source: Google trends)

4.1.5. Interest in Sustainable Finance (SuFi)

Figure 5 presents the data for global web search for information about sustainable finance (SuFi). Figure 5 shows that interest in web information about sustainable finance exceeded the 50-point mark in Luxembourg and St Helena. This implies that web search for information about sustainable finance was greater in Luxembourg and St Helena than in any other country in the world during the period. Other countries that recorded some level of interest in sustainable finance are Hong Kong, Singapore and Switzerland. The high interest in internet information about SuFi in Luxembourg and St Helena is due to the growing interest in sustainable development in these two countries. In contrast, there is very low interest in internet information about sustainable finance in countries like Russia and Turkey. The low interest is due to a general lack of interest in sustainable finance among the population in these countries.

Figure 5: Global interest in web information about sustainable finance (SuFi)
 (from January 2004 to December 2021)

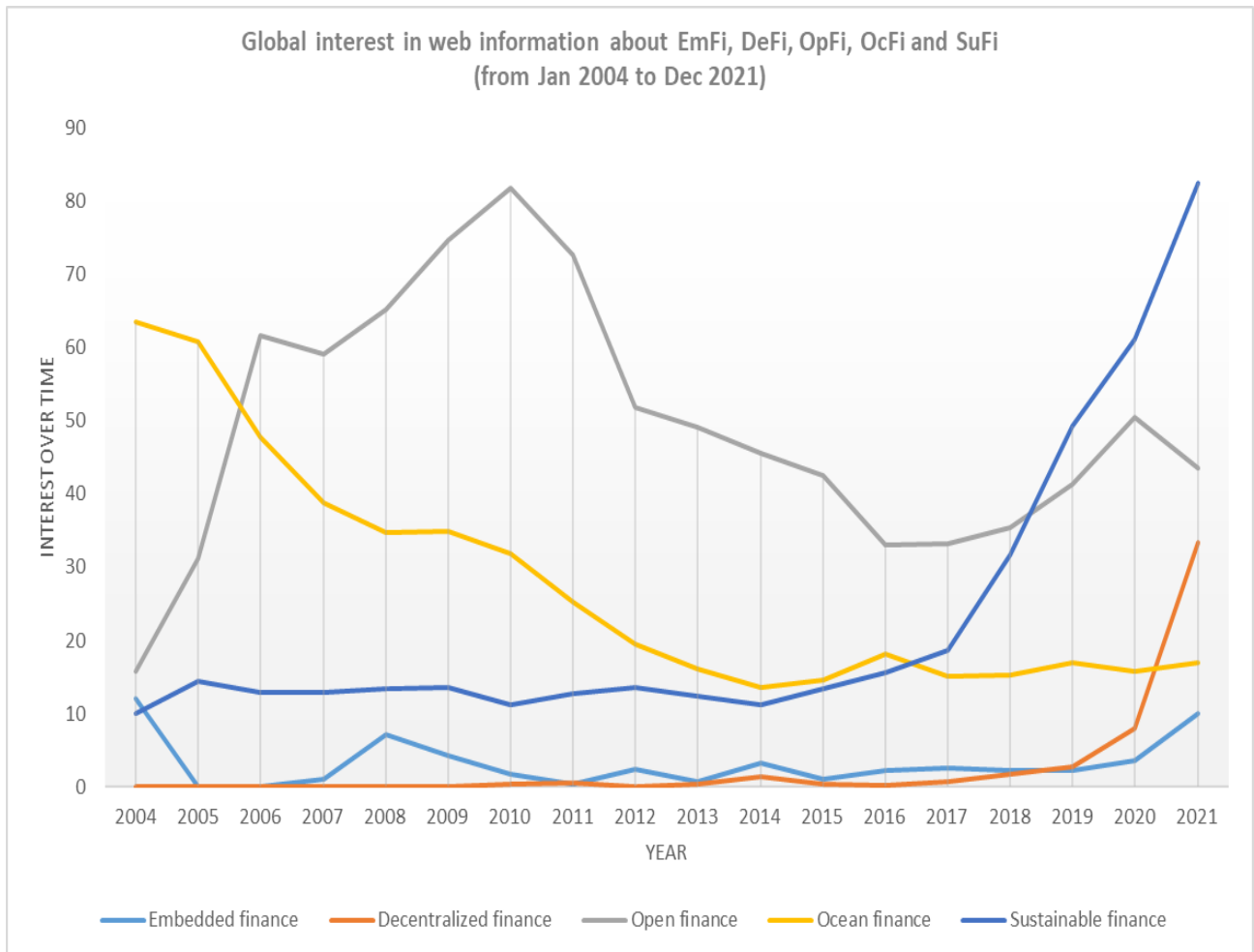


(Source: Google trends)

4.1.6. Relationship between DeFi, EmFi, OcFi, SuFi and OpFi

Figure 6 shows that global web search for information about open finance (OpFi) increased during the 2007 to 2009 global financial crisis and reached a significant peak in 2010. Afterwards, global web search for information about open finance declined continuously and fell below the 50-point mark in 2016, 2017 and 2018. Global interest in ocean finance decreased during the 2007 to 2009 global financial crisis. Global web search for information about open finance increased during the first wave of the COVID pandemic and declined in the second wave of the COVID pandemic in 2021. Global web search for information about decentralized finance (DeFi) was very low in 2017 and 2018 and witnessed a sharp rise during the first wave and second wave of the COVID pandemic in 2020 and 2021. Global web search for information about embedded finance grew in 2008 in the middle of the global financial crisis and during the COVID pandemic from 2020 to 2021. Overall, the graph in figure 6 shows that global web search for information about OpFi and EmFi increased during the financial crisis years while global web search for information about DeFi, SuFi and EmFi increased during the pandemic years.

Figure 6: Global interest in web information about EmFi, DeFi, OpFi, OcFi and SuFi
(from January 2004 to December 2021)



(Source: Google trends)

4.2. Correlation analysis

The Pearson correlation result is reported in table 1. The correlation matrix in table 1 shows that there is a significant positive correlation between global interest in DeFi information and global interest in EmFi information. This indicates that people who were interested in internet information about decentralized finance were also interested in internet information about embedded finance. Also, there is a significant negative correlation between global interest in EmFi information and global interest in OpFi information. This indicates that people who were more interested in internet information about embedded finance were less interested in internet information about open finance. There is also a significant negative correlation between global

interest in OpFi information and global interest in OcFi information. This indicates that people who were more interested in internet information about open finance were less interested in internet information about ocean finance. There is also a significant positive correlation between global interest in EmFi information and global interest in OcFi information. This indicates that people who were more interested in internet information about embedded finance were less interested in internet information about ocean finance. There is also a significant positive correlation between global interest in EmFi, OcFi and SuFi information. This indicates that people who were more interested in internet information about embedded finance were less interested in internet information about sustainable finance.

Table 1. Pearson correlation between DeFi, EmFi, OpFi, OcFi and SuFi

Variables	Interest in EmFi	Interest in DeFi	Interest in OpFi	Interest in OcFi	Interest in SuFi
Interest in EmFi	1.000 ----- -----				
Interest in DeFi	0.201*** (2.99) ((0.00))	1.000 ----- -----			
Interest in OpFi	-0.151** (-2.23) ((0.03))	-0.091 (-1.34) ((0.18))	1.000 ----- -----		
Interest in OcFi	0.274*** (4.16) ((0.00))	0.121* (1.78) ((0.08))	-0.387*** (-6.13) ((0.00))	1.000 ----- -----	
Interest in SuFi	0.215*** (3.22) ((0.00))	0.139** (2.06) ((0.04))	-0.222*** (-3.34) ((0.00))	0.533*** (9.22) (0.00))	1.000 ----- -----

P-values are in double parentheses. T-values are in single parenthesis. ***, **, * denote statistical significance at the 1%, 5% and 10% level.

4.3. OLS and GMM Regression Coefficient Matrix

The regression coefficient matrix is used to determine the association between EmFi, DeFi, OpFi, SuFi and OcFi as shown in table 1. I focus on the coefficient sign and the statistical significance of the coefficient of the variables in the univariate regression models. The purpose of the estimations is to check whether the coefficients of the regression estimations confirm the association in table 1 above. To do this, I specify a one dependent variable and one independent variable regression model as shown in table 2 below. The result in table 2 shows that the coefficients are all positive and statistical significance in all the models. This indicates that OcFi, OpFi, EmFi, SuFi and DeFi are significantly related to each other in the OLS estimations in table 2. The GMM estimations in table 3 also report coefficient signs that are positive and some coefficients are statistically significant. From the results in table 2 and 3, it can be seen that interest in EmFi and DeFi, OpFi and DeFi, OpFi and EmFi, OcFi and EmFi, OcFi and OpFi, SuFi and EmFi, and SuFi and OcFi are significantly related.

Table 2. OLS Regression Coefficient matrix					
	(1)	(2)	(3)	(4)	(5)
	<i>Interest in DeFi</i>	<i>Interest in EmFi</i>	<i>Interest in OpFi</i>	<i>Interest in OcFi</i>	<i>Interest in SuFi</i>
	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
<i>Interest in DeFi</i>	-	0.284*** (4.44)	1.533*** (3.92)	0.284*** (3.73)	0.284*** (3.89)
<i>Interest in EmFi</i>	0.297*** (4.44)	-	1.745*** (4.41)	0.465*** (6.31)	0.385*** (5.32)
<i>Interest in OpFi</i>	0.044*** (3.93)	0.048*** (4.41)	-	0.061*** (4.88)	0.064*** (5.39)
<i>Interest in OcFi</i>	0.214*** (3.73)	0.336*** (6.31)	1.626*** (4.88)	-	0.606*** (11.91)
<i>Interest in SuFi</i>	0.232*** (3.89)	0.301*** (5.31)	1.849*** (5.39)	0.656*** (11.91)	-

Table 3. GMM Regression Coefficient matrix					
	(1)	(2)	(3)	(4)	(5)
	<i>Interest in DeFi</i>	<i>Interest in EmFi</i>	<i>Interest in OpFi</i>	<i>Interest in OcFi</i>	<i>Interest in SuFi</i>
	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)	Coefficient (t-statistic)
<i>Interest in DeFi</i>	-	0.928*** (2.67)	13.487** (2.16)	1.104 (1.43)	1.161 (1.59)
<i>Interest in EmFi</i>	0.840** (2.20)	-	18.339*** (6.67)	1.094*** (4.80)	1.021*** (4.79)
<i>Interest in OpFi</i>	0.018* (1.92)	0.067*** (5.04)	-	0.059*** (5.20)	0.061*** (4.98)
<i>Interest in OcFi</i>	0.368 (1.28)	0.655*** (5.31)	9.927*** (5.27)	-	0.804*** (4.15)
<i>Interest in SuFi</i>	0.415 (1.33)	0.668*** (4.79)	10.908*** (5.11)	0.825*** (3.62)	-

The GMM instruments are the one-year lag of the dependent variable in each regression model.

5. Conclusion

This study analysed global interest in information about decentralized finance (DeFi), embedded finance (EmFi), open finance (OpFi), ocean finance (OcFi) and sustainable finance (SuFi), and the causal relationship among them.

The findings revealed that global interest in internet information about embedded finance (EmFi) was more popular in Asian and European countries. Global web search for internet information about OcFi decreased during the financial crisis. Global web search for internet information about OpFi and EmFi increased during financial crisis years while global web search for internet information about DeFi, SuFi and EmFi increased during the pandemic years. There is a significant positive correlation between interest in decentralized finance, embedded finance, ocean finance and sustainable finance. Also, there is a significant negative correlation between interest in embedded finance and interest in open finance. The regression coefficient matrix shows that open finance, embedded finance, ocean finance, decentralized finance and sustainable finance are significantly related.

The findings from the correlation analysis have implications. Firstly, it indicates that people who were more interested in internet information about decentralized finance were also interested in internet information about embedded finance, sustainable finance and ocean finance while people who were more interested in internet information about embedded finance were less interested in internet information about open finance. The implication is that there is a need to

increase the amount of internet information about decentralized finance in order to encourage more people to also learn about embedded finance, sustainable finance and ocean finance, thereby making it easier for people to embrace DeFi, EmFi, OcFi and SuFi solutions in their daily lives. Private sector agents and policy makers should use incentives to encourage people to develop interest in internet information about decentralized finance, embedded finance, open finance, ocean finance and sustainable finance. Policy makers should also create a policy environment that embrace DeFi innovations as it can lead to greater search for internet information about decentralized finance which can also spur interest in embedded finance, sustainable finance, open finance and ocean finance based on their correlation with one another.

Future studies can extend this study by investigating whether interest in the blockchain is related to interest in decentralized finance using internet search data. Future studies can also examine the relationship between interest in DeFi, OpFi, SuFi, OcFi and EmFi in specific country contexts. Future studies can also examine the lag from information search to acceptance of DeFi, OpFi, EmFi, OcFi and SuFi innovations.

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