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Analyzing startup ecosystem through corporate networks based on investment relation of venture capitals in unicorns

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Abstract

We propose a method to build a corporate investment network based on the investment relationship between unicorns and venture capital (VC) and to analyze the characteristics of the startup ecosystem. Unicorns, unlisted startup companies with valuation of over $ 1 billion, are the leading drivers in innovation. For startup companies to grow into unicorns, it is important for them to be supported in startup ecosystem, where VCs play a very important role. In this research, we propose a method to build corporate investment networks of unicorns and VCs around the world, and to quantitatively analyze the characteristics of the relationship between the unicorns and the VCs and the diffusion of startup activities from inter-industry and international viewpoints, and the factors that affect the valuation value of unicorns and performance of VCs. The proposed method is able to quantitatively measure the characteristics of the startup ecosystem and effective to promote produce of unicorns.

Keywords: Business ecosystem; Capital-based corporate network; Network analysis; Conglomerate discount; Open innovation

1. Introduction

In business, a unicorn is an unlisted startup company with a value of over $ 1 billion. For startup companies to grow into unicorns, it is important for them to be supported in the startup ecosystem, where venture capitals (VCs), which provide funds and managerial support, play an important role for them.

Startup companies, particularly unicorns, are the leading drivers of innovation, and clarifying the actual situation of unicorns is very important for promoting innovation. However, it is not easy to quantitatively clarify the actual situation of them due to reasons such as being unlisted.

In this research, we propose a method to build corporate investment networks of unicorns and VCs around the world based on the investment relationship, and to quantitatively analyze the characteristics of the relationship between the unicorns and the VCs, and the diffusion of startup activities from inter-industry and international viewpoints, and the factors that affect the valuation of unicorns and performance of VCs.

2. Related Work

2.1. Business Ecosystem

Ecosystem often means a biological system, but in a broad sense, it means complex systems such as an industrial or business system where various actors exist. Regarding the ecosystem in industry and business, Mcintyre et al. (2016) classifies ecosystem into three perspectives; (1) Industrial organization economics, (2) Technology management, and (3) Strategic management, and shows future research issues [1]. Tsujimoto et al. (2018) also classify it into four perspectives; (1) Industrial ecology, (2) Business ecosystem, (3) Platform management, and (4) Multi-actor network [2].

In this research, referring to these previous studies, we analyze the relationship between unicorns and VCs in the

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business ecosystem as "economic dependencies and cooperative relationships between interacting companies".

2.2. Unicorn and Startup Ecosystem

In business, a unicorn is an unlisted startup company with a value of over $ 1 billion. The term was named in 2013 by venture capitalist Aileen Lee, choosing the mythical animal to represent the statistical rarity of such successful startup companies [3].

There are some studies on unicorns conducted. Dellermann et al. (2017) predicts successful startup companies using machine learning [4]. Gorna et al. (2020) proposes a valuation model for unicorns [5].

As for startup ecosystems, Sussan et al. (2017) provide a conceptual framework for studying entrepreneurial activity in the digital age using two existing concepts; (1) the digital ecosystem and (2) the entrepreneurial ecosystem [6]. Furthermore, as for the relationship between unicorns and VCs, Bock et al. (2020), using the same unicorn list provided by CB Insights as in this paper, quantitatively analyze the effects of factors such as VC on valuation of unicorns [7]. Though this study analyzes the impact of individual VCs on individual startup companies, it does not analyze the relationship between multiple unicorns and multiple VCs in the startup ecosystem.

2.3. Network Analysis of Business Ecosystem

In this paper, we quantitatively analyze the startup ecosystem through social networks based on the investment relationship between unicorns and VCs.

As a macro-level analysis of social networks, "Small world network" by Watts and Strogatz (1998) and "Scale free network" by Barabashi and Albert (1999) have attracted attention, and various studies on network structure have been conducted [8][9]. On the other hand, as a micro-level analysis on social networks, various studies such as Davis (1997) and Newman (2004) have been conducted and applied to organizational activities in business, academic societies, and so on [10][11].

Research on applying social network analysis to economics has also been done by various approaches. Jackson et al. (2017) extensively reviews the application of network analysis to economics and discusses network structure and endogeneity of economic behavior [12]. Kojaku et al. (2018) modeled the propagation of financial crises through networks [13]. Nishino et al. (2018) clarified the general mechanism to form business ecosystem using agent-based simulation [14]. Mizuno et al. (2019) measured the influence of investors on companies and clarified the difference in investment strategies between government and private financial institutions [15]. Fujita et al. (2021) quantitatively analyzed the business ecosystems of corporate groups in wide range of industries from the viewpoints of business diversification and decentralization in each industry [16].

In this paper, we focus on the startup business ecosystem, and quantitatively analyze the characteristics of the relationship between unicorns and VCs, and the diffusion of startup activities from inter-industry and international viewpoints, and the factors that affect the valuation of unicorns and performance of VCs.

3. Method

3.1. Database

In this paper, we analyze the unicorn list provided by CB Insights. The list includes 501 unicorns as of November 2020 [17]. Among them, Byte Dance, Didi Chuxing, SpaceX, Stripe and Airbnb are listed as the largest unicorns. The list includes the year when each unicorn was on the list, the industry of each unicorn, and the VCs which invested in each unicorn.

3.2. Procedure of Analysis

The procedure of the analysis in this paper is shown below.

Step 1. Using the unicorn list provided by CB Insights, rank the valuation of unicorns, the performance of VCs which invests unicorns, and the valuation of unicorns by industry and by country.

Step 2. Build an investment network based on the investment relationship between the unicorns and the VCs, and visualize the investment networks. If a VC is investing in a unicorn, create an edge between the unicorn and the VC as nodes, and build a bipartite graph (Unicorn-VC investment network) consisting of all the edges of the unicorn and the VC. If one company is both a unicorn and a VC, treat this company as separate two companies.

Step 3. Decompose this bipartite graph into a unicorn graph (Unicorn investment network) and a VC graph (VC investment network). When building a Unicorn investment network and a VC investment network, build a directed graph. For the Unicorn investment network, the directed graph is built based on the date when the unicorn appeared, for the first time, on the CB Insights unicorn list, going from the old unicorn to the new unicorn. For VC investment networks, the directed graph is built based on the date when the VC appeared, for the first time, on the CB Insights unicorn list as an investor in a unicorn, going from the VC investing in an older unicorn to the VC investing in a newer unicorn.

Step 4. Calculate the following node features and the network features.

(1) Each unicorn's Network centralities, Expansion, and Elongation in the Unicorn investment networks

(2) Each VC's Network centralities, Expansion, and Elongation in VC investment networks

(3) Number of permutations of the industries and number of permutations of the countries in all the edges composed of two unicorn nodes of Unicorn investment networks

Here, "Network centralities" include five representative centrality indicators (Degree Centrality, Closeness Centrality, Betweenness Centrality, Eigen

Centrality, and Page Rank) and In-degree Centrality and Out-degree Centrality. “Elongation” indicates the length of the maximum path in the directed graph extending from a certain node, and “Expansion” indicates the number of the total terminal nodes in the directed graph reached from a certain node.

Step 5. Conduct regression analysis on the factors that affect the unicorn valuations and VC performances. In the regression analysis, explanatory variables, which are of the unicorn features and VC features, are narrowed down by using the variable reduction method (Backward Elimination).

(1) As for the factors that affect the unicorn valuations, conduct multiple linear regression analysis by using the unicorn features. Explained variable is Valuation of each unicorn. Explanatory variables are unicorns' Network centralities, Expansion, Elongation, and Density in the Unicorn investment networks (10 explanatory variables in total).

Here, “Density” indicates the network density in Unicorn investment network.

(2) As for the factors that affect the VC performances, conduct multiple linear regression analysis by using VC features. Explained variable is the total Valuations of the unicorns invested by each VC (performance). Explanatory variables are VCs' Network centralities, Expansion, Elongation and Density in the VC investment network, #industries, #countries, and #unicorns (13 explanatory variables in total).

Here, “Density” indicates the network density in VC investment network. “#industries” (the number of industries) is the total number of industries to which the unicorns invested by the VC belong. “#countries” (the number of countries) is the total number of countries to which the unicorns invested by the VC belong. And “#unicorns” (the number of unicorns) is the total number of unicorns invested by the VC.

4. Result

This section shows the result of the analysis of 501 unicorns based on the procedure in Section 3.

4.1. Overview of Unicorns and VCs

Table 1 shows the top 10 unicorns ranked by the valuation extracted from CB Insights' unicorn list. The total valuation of the 501 unicorns is $ 1,596 Billion. The unicorn with the highest valuation is Bytedance, and Table 1 shows that the USA unicorns account for 6 companies and the Chinese unicorns account for 3 companies in the top 10 unicorns.

Table 2 shows the top 10 VCs ranked by the total valuation of unicorns invested in by each VC (performance). The total number of VCs which invested in 501 unicorns is 695. Each performance in Table 2 is the sum of the total valuation of the invested unicorns, and the investment share in unicorns by each VC is not taken into consideration. Accordingly, the total performance ($ 4,721 Billion) of VCs in Table 2 does not match the total valuation ($ 1,569 Billion) of unicorns in Table 1. The VC with the highest performance is Sequoia Capital China. Top five VCs account for 16% of the total performance.

Table 3 shows the top 10 industries ranking by the total valuation of unicorns. The valuation in Table 3 is the sum of the valuation of unicorns in the industry. The industries with the highest valuation are Fintech and AI. Fintech and AI accounting for 31% of the total valuation.

Table 4 shows the top 10 countries ranked by the total valuation of unicorns. The valuation in Table 4 is the sum of the valuation of the unicorns in the country. The country with the highest valuation is USA, and the next country is China. USA and China accounting for 77% of the total valuation.

Table 1. Major unicorns (Top 10 unicorns by valuation)

No.	Unicorn	Valuation ($B)	Country	Industry
	Total	1,596		
1	Bytedance	140	China	Artificial intelligence
2	Didi Chuxing	62	China	Auto & transportation
3	SpaceX	46	USA	Other
4	Stripe	36	USA	Fintech
5	Airbnb	18	USA	Travel
6	Kuaishou	18	China	Mobile & telecommunications
7	Instacart	18	USA	Supply chain, logistics, & delivery
8	Epic Games	17	USA	Other
9	DoorDash	16	USA	Supply chain, logistics & delivery
10	One97 Communications	16	India	Fintech

Table 2. Major VCs (Top10 VCs by performance)

No.	VC	Performance ($B)
	Total	4,721
1	Sequoia Capital China	190
2	Softbank Group	184
3	Sina Weibo	143
4	SIG Asia Investments	140
5	Sequoia Capital	98
6	Tiger Global Management	86
7	capitalG	68
8	Founders Fund	67
9	Matrix Partners	64
10	Softbank Corp.	63

Table 3. Industries (by the total valuation of unicorns in the industry)

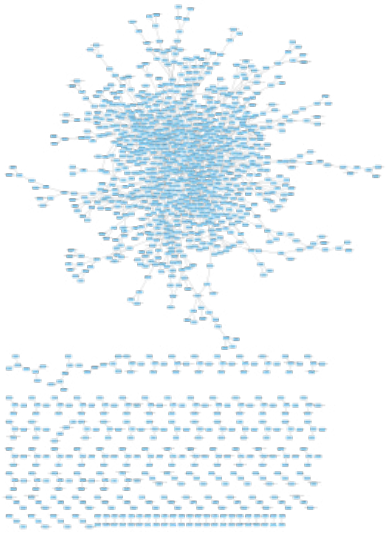
Industry	Valuation ($B)
Total	1,596
Fintech	249
Artificial intelligence	242
E-commerce & direct-to-consumer	172
Auto & transportation	138
Internet software & services	131
Other	114
Supply chain, logistics, & delivery	97
Hardware	81
Health	80
Mobile & telecommunications	75
Edtech	56
Travel	45
Consumer & retail	42
Cybersecurity	36
Data management & analytics	35
Education	2

Table 4. Major countries (Top 10 countries by the total valuation of unicorns in the country)

No.	Country	Valuation ($B)
	Total	1,596
1	USA	718
2	China	517
3	India	88
4	UK	65
5	South Korea	30
6	Indonesia	26
7	Germany	25
8	Singapore	19
9	Brazil	18
10	Sweden	16

4.2. Relation between Unicorns and VCs

Fig. 1 shows a Unicorn-VC investment network. It shows that the network is composed of one large cluster and many small clusters.



Fig。 1. Unicorn-VC investment networks

4.3. Diffusion of Investment among Industries

Fig. 2 shows the industry heatmap for the nodes in the Unicorn investment networks. The numbers in the heatmap cells indicate the number of edges from the node of the unicorn in the industry on the vertical axis to the node of the unicorn in the industry on the horizontal axis of the heatmap. Fig. 3 shows the network diagram of the heat map of Fig. 2.

Fig. 2 and Fig. 3 show the following three points. Firstly, there are particular industries where VCs are investing in multiple other industries in addition to within the industry. An example is shown below.

- “Internet software & services” and “E-commerce & direct-to-consumer” are closely related to several other industries. Network centralities of the industries are both the largest.

Secondly, there are particular industry groups where many VCs are mutually investing within the industry group. An example is shown below.

- “Internet software & services”, “E-commerce & direct-to-consumer” and “Fintech” are closely related to each other.

Thirdly, the order of investment is asymmetric between the two industries. The number of VCs investing in one industry and then in another industry is larger than the number of VCs investing in the inverse way. Examples are shown below.

- The number of investments in “Artificial intelligence”, “Hardware” and “Edtech” after “E-commerce & direct-to-consumer” is larger than the number of investments in the inverse way.
- The number of investments in “Fintech” after “Edtech” is larger than the number of investments in the inverse way.

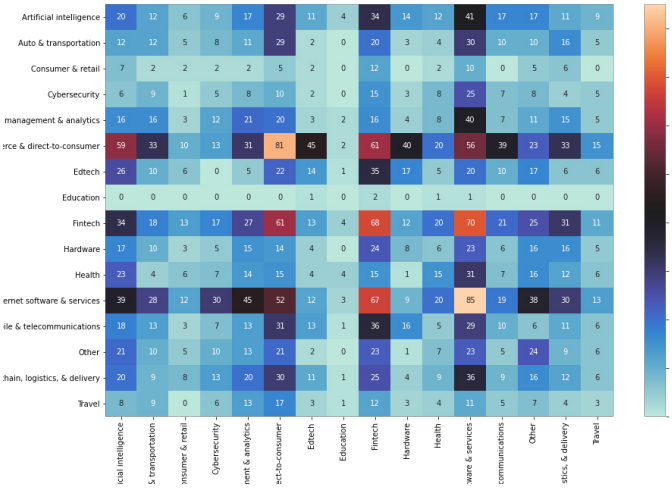


Fig. 2. Inter-industry investment heatmap

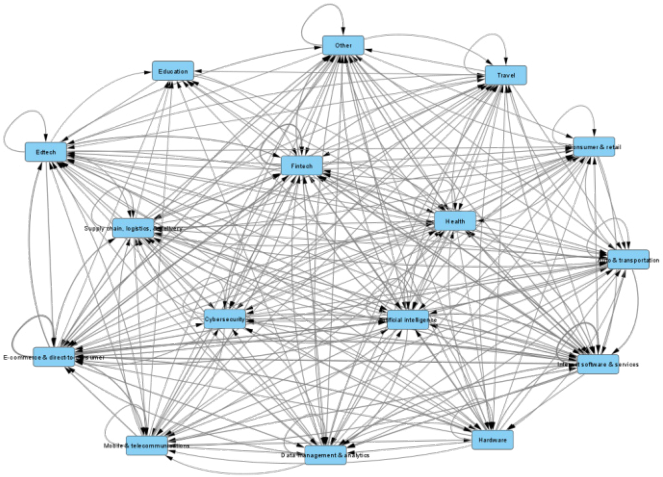


Fig. 3. Inter-industry investment network

4.4. Diffusion of Investment among Countries

Fig. 4 shows the country heatmap for the nodes in the Unicorn investment networks. The numbers in the heatmap cells indicate the number of edges from the node of the unicorn in the country on the vertical axis to the node of the unicorn in the country on the horizontal axis of the heatmap. Fig. 5 shows the network diagram of the heat map of Fig. 4.

Fig. 4 and Fig. 5 show the following three points. Firstly, there are particular countries where VCs are investing in

multiple other countries in addition to within the industry. An example is shown below.

- USA and China are closely related to several other countries. Network centralities of the countries are the top 1 and 2.

Secondly, there are particular country groups where many VCs are mutually investing within the country group. An example is shown below.

- USA, China and India are closely related to each other.

Thirdly, the order of investment is asymmetric between the two countries. The number of VCs investing in one country and then in another country is larger than the number of VCs investing in the inverse way. Examples are shown below.

- The number of investments in USA after China is larger than the number of investments in the inverse way
- The number of investments in Japan after USA is larger than the number of investments in the inverse way

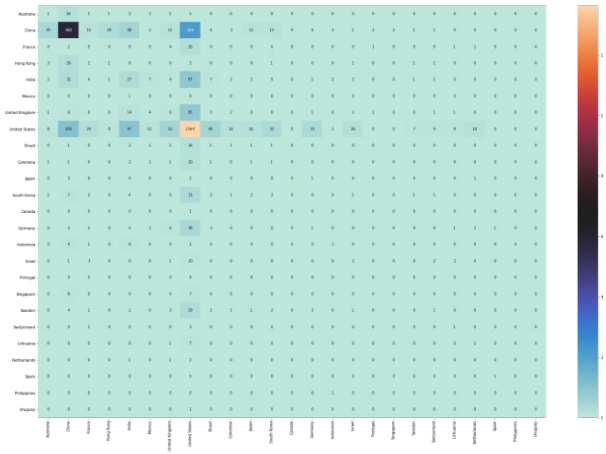


Fig. 4. Inter-national investment heatmap

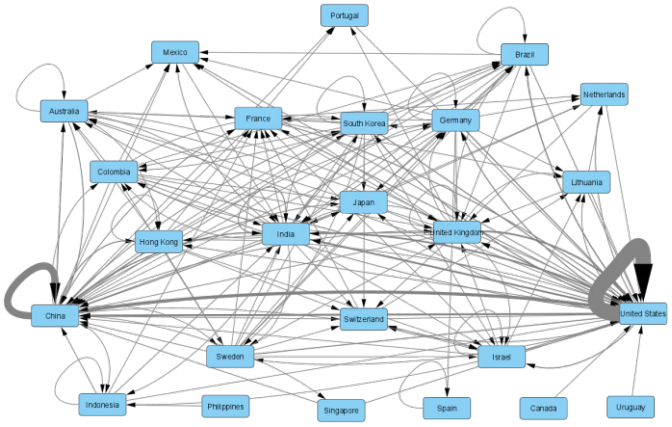


Fig. 5. Inter-national investment network

4.5. Factors Affecting the Valuation of Unicorns

As a result of conducting multiple regression analysis according to the procedure of Step 5 in Section 3.2, it is found that "Expansion" significantly affects valuation of the unicorns ($p < 0.05$).

Table 5. The result of liner regression of Unicorn valuation

Valuation of unicorn ($B)	coef	std err	P>|t|
Out-degree centrality	0.099	0.070	0.159
Expansion	0.179	0.070	0.011

4.6. Factors Affecting the Performance of VCs

As a result of conducting multiple regression analysis according to the procedure of Step 5 in Section 3.2, it is found that "Betweenness centrality", "Expansion", and "#unicorns" significantly affect VC performance ($p < 0.01$).

Table 6. The result of liner regression of VC performance

Total valuation of unicorns ($B)	coef	std err	P>|t|
Betweenness centrality	0.195	0.043	0.000
Expansion	0.136	0.032	0.000
Number of unicorns	0.481	0.048	0.000

5. Discussion

5.1. Ecosystem of Unicorn and VCs sharing Startup Success

In the CB Insights' unicorn list, the number of edges of the Unicorn-VC investment network between 501 unicorns and 695 VCs was 1,385. This shows that 695 VCs invest in about 2.0 unicorns in average out of 501 unicorns, and 501 unicorns are invested in by about 2.7 in average out of 695 VCs. Furthermore, Fig. 1 shows that most unicorns through the VCs and most VCs through the unicorns form one huge chained cluster. This suggests that the unicorns, successful startup companies, and the VCs have built one community as "Scale free network" which follows "Power law".

In general, VCs not only provide funds to startup companies, but also provide managerial knowledge on starting business by dispatching directors to the companies. On the other hand, the existence of the above-mentioned huge unicorn and VC community suggests that the VCs in turn gains successful entrepreneurial experience through the unicorns, successful startup companies, that is, there exists a startup ecosystem within which the unicorns and the VCs are sharing the knowledge of business success.

5.2. Diffusion of Startup Success across Industries

Fig. 3 shows that startup knowledge diffuses across industries through VCs, and that diffusion is asymmetric. For realization of innovation, it is important to search for knowledge in various fields and combine knowledge in different fields to obtain new knowledge. Schumpeter (1926) states that economic development requires a "new combination" (Neue Kombination = New Combination) [18]. Chesbrough (2005) also discussed the importance of open innovation and states the importance of collaboration in business [19]. The existence of one huge cluster mentioned above suggests that the startup knowledge in various

industries is combined within the cluster to accelerate innovation, and that the startup growth in one industry diffuses to other industries.

5.3. Diffusion of Startup Success across Countries

Fig. 5 shows that startup knowledge diffuses internationally through VCs, and that diffusion is asymmetric. Before the analysis in this research, we assumed that the success knowledge of USA startup companies would be transmitted to China and other countries through VCs, but the result of the analysis is the opposite. It is assumed that the reason for the result is because VCs operating in China are actively investing in USA. The analysis in this paper do not include VC nationality data. Thus further analysis including VC nationality is desired in the future.

5.4. Detection and Prediction of Nest Startup Success

Fig. 3 and Fig. 5 show the diffusion of successful startups through VCs. They do not indicate changes in unicorn valuation nor VC performance based on long-term data, but the result of analysis based on one time point (November 30, 2020) data. However, the result in Sections 4.5 and 4.6 show that the larger the Unicorn investment networks and VC investment networks expand, the better the valuation of the unicorns and the performance of the VCs grow. Therefore, by analyzing changes in the valuation of unicorns and the performance of VCs, it may be possible to detect or predict unicorns whose valuation will increase, VCs whose performance will increase, and new industrial fields in which such unicorns and VCs will operate. The studies to detect and predict these are desired in the future.

6. Conclusion

We proposed a method to build a corporate investment network based on the investment relationship between unicorns and VC and to analyze the characteristics of the startup ecosystem. We built corporate investment networks of over 500 unicorns and VCs around the world, and quantitatively analyzed the characteristics of the relationship between the unicorns and the VCs, and the diffusion of startup activities from inter-industry and international viewpoints, and the factors that affect the valuation of unicorns and performance of VCs.

The result showed the followings. (1) Unicorns and VCs form one huge cluster. This suggests existence of an ecosystem, a community within which startup companies and VCs shares the successful startup knowledge, (2) startup knowledge diffuses across industries through VCs, and diffusion is asymmetric, and (3) startup knowledge diffuses internationally through VCs, and diffusion is asymmetric.

The analysis in this paper has limitations. The analysis does not include VC nationality data nor long-term unicorn valuation data. However, the proposed method is able to quantitatively measure the characteristics of inter-industry and international startup ecosystem well as the factors that affect the unicorn valuation and VC performance, and effective to promote produce of unicorns.

Acknowledgments

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