Analyzing VC Influence on Startup Success: They Might Not Be Good For You

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Abstract We study the impact of venture capitalists on startup success using social network analysis. Using multiple sources, we compile a unique dataset of 3199 US-based technology startups and their board members, from which we generate and analyze the interlocking directorates network (formal network) and the Twitter activity network (informal network). We define three metrics of success: startup funding (collected from Crunchbase), annual sales (collected from OneSource), and return-on-investment (annual sales / funding). We find that startups with more VCs on their board are more centrally located in the formal network, tend to receive greater funding, have greater annual sales, yet a smaller return-on-investment. We also find that VCs are significantly more central in the Twitter network than non-VCs, and they have greater Twitter popularity (number of followers / number of people they follow). Interestingly, VCs tweet significantly less than non-VCs. Our results indicate that VCs carry a significant amount of capital, both financially as well as socially, which they transmit to the startups they become involved with, however their active participation on the boards of startups leads to lower ROI.

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[2] https://www.irs.gov/uac/soi-tax-stats-individual-income-tax-statistics-2014-zip-code-data-soi

1 Introduction

There is much uncertainty involved with early stage technology startups (Giardino et al 2015). Venture capitalists are faced with literally million dollar questions as they seek to evaluate startups, to determine the potential of an investment. Likewise, entrepreneurs are faced with equally valuable questions as they seek venture capitalists from whom to not only gain funding, but also support and mentorship (Woike 2015).

Fundamentally, we aim to investigate the question of how venture capitalists, in particular through their networking behavior, influence the success of a startup. To answer this broad question, we adopt a network theory approach, in which we construct social networks of the board members of each startup. We choose to study the board of directors of a startup, as board directors have a great deal of influence over a startup due to their financial, intellectual, and social capital resources. Furthermore, board members often sit on multiple boards, and therefore may share their resources with multiple startups. The resulting network formed by board membership represents a communication network, through which critical resources and information flows.

Collaborative Innovation Networks (COINs) are self-organizing social systems in which self-motivated individuals collaborate to achieve a common goal (Gloor 2005). We believe the board membership network bears some similar traits to a COIN network - within this network, multiple players, namely VCs and entrepreneurs, strive to create something new - a new venture and financial gain. That said, the extent to which such a network is actually "collaborative" remains an open question. Specifically, we pose the question: to what extent do venture capitalists in this network contribute to the overall success of the entrepreneurs and their startups?

To investigate this question, we first construct a formal network, an interlocking directorates network composed of companies (the nodes) and links between two companies who share at least one board member (Mizruchi 1996). We look at the position of successful startups in this network and compare this to the position of startups with many VCs on their boards. Secondly, we construct an informal social network composed of the Twitter activity of the individuals in our formal network, and look at the behavior of venture capitalists in this network. By looking at venture capitalists' influence in these networks, we develop evidence that informs our response to the ultimate research question - how do venture capitalists influence the success of startups.

2 Background and Related Work

Venture capital (VC) is well established as one of the key driving forces in the American entrepreneurial ecosystem (Insight 2007). According to the National

Venture Capital Association, in 2015 nearly $60 billion in venture capital was deployed across 4,380 deals. More than 30% of those deals were to companies receiving venture investment for the first time (Franklin & Haque, 2016). That said, research studies have not provided consistent conclusions regarding the impact of VC investments on entrepreneurial firms, and whether this impact is a net positive or negative (Bertoni 2011*)*. Although the answer is likely, "it depends", the question is worthy of continued rigorous analysis.

Advocates for the positive influence of VCs claim that VCs serve three main roles to identify and promote successful startups:

1. "Screening": VCs choose to invest in high quality companies with promising potential. They are experienced at selecting for certain criteria that predict success, such as technical expertise and founder commitment (Chan 1983, Amit 1998).
2. "Monitoring": VCs track the status of their portfolio companies, comparing investments with market trends and opportunities. They protect the value of their investments by adding credibility and prestige to those companies they invest in (Lerner 1995, Kaplan 2003).
3. "Coaching": VCs provide advice and support to their portfolio companies with the intent of improving their chances of success and, in return, the return on their investment. This may include connecting the firm with resources, networking, assisting with recruitment, providing experience, advice, and mentoring (Hellmann 2002, Hellmann 2000).

Multiple studies have demonstrated the correlation between VC involvement and startup success: VC-backed firms have faster growth, faster times-to-market of their products, more patents, higher productivity, greater innovation, higher efficiency, and are more likely to have a successful exit (IPO or acquisition) (Wright and Robbie 1998, Bernstein et al. 2015, Chemmanur et al. 2008). That said, many studies fail to isolate the influence of the VC themself on the startup, as it is often difficult to decouple the effects of screening from those of monitoring and coaching (Lahr and Mina, 2016).

However, reasons and explanations abound which indicate just the opposite; that venture capitalists can and do have a negative influence on startups and their entrepreneurs. Foremost, a large body of research exists regarding conflicts between startup entrepreneurs and VCs. Prior research has identified three main areas of VC-CEO conflicts: conflicts of interests and unfavorable attributions, conflicts of inefficient collaboration, and conflicts of VC-CEO mismatch (Khanin 2013). Conflict does not necessarily have a negative impact on the success of a startup (Higashide and Birley 2002). However, at high levels of occurrence and intensity, conflict is generally considered to be costly to those involved (Reve and Stern 1989). Furthermore, the negative impacts of VC investments have been demonstrated analytically for a number of geographies external to the US, including China, France, and Singapore (Xi and Su-Sheng 2016, Pommet 2017, Wang et al. 2003), although to the authors' knowledge no studies in the US have reached similar conclusions. Furthermore, there seems to be a growing sentiment

emanating from Silicon Valley that entrepreneurs should be dubious, or at a minimum cautious, of venture capitalist investment (Mullins 2014).

Additionally, a number of studies indicate that communication networks have a strong influence over the success of innovation in companies. In one study of researchers at biotech startups, it was shown that innovation success is correlated with real-world communication intensity (Allen et al 2016). One may wonder if communication intensity is independent of geographic constraints, especially in our world of digital communication tools. Another study, however, demonstrated communication intensity among biotechnology companies was significantly higher among companies that were geographically close (Allen et al 2009). A third study analyzed the digital social networks of entrepreneurs, and found no positive effects of virtual network size on entrepreneur success (Gloor et al 2016). Quality of communication, not quantity, appeared to dominate in the digital space. It remains unclear, however, how these findings regarding communication in the physical vs. digital space relate to the entrepreneur-venture capital ecosystem.

In this research, we attempt to disentangle the conflicting messages coming from academia and industry regarding the impact of VCs on startup success. By applying a unique approach, namely a network theory analysis of the board membership network and Twitter social network, we believe our work provides a unique contribution to the literature.

3 Data and Methods

3.1 Network Construction

To construct and analyze our VC-startup networks, we compiled a unique dataset from multiple sources. We limited the scope of our study to tech startups founded in the US in the past five years. We extracted 3199 startups from the S&P Capital IQ database (https://www.capitaliq.com), including a list of the board members of each startup as well as whether each individual was a VC or not. We constructed the interlocking directorates network based on the 8474 total board members, resulting in a network with 3199 nodes (1 per startup) and links between startups that share at least one board member. We used the Condor software tool (www.galaxyadvisors.com) to calculate three centrality measures on this network: betweenness, degree, and closeness. Betweenness centrality measures the extent to which a vertex lies on paths between other vertices. Closeness centrality measures the mean distance from a vertex to other vertices. Degree centrality measures the number of neighbors a node has. These standard measures of centrality generally indicate how central a node is in the network, and therefore how critical to information flow that node is.

We also constructed an informal social network with which to compare against the formal network, as well as inform our understanding of VC communication

behavior. We chose Twitter as the data source for this network as Twitter is the social media platform most extensively used by startups and investors, and broadly used by the business community (Wu et al 2015). We foremost wrote python scripts to query Twitter's Search API to identify the corresponding Twitter handle (ID) for the 8474 people in our formal interlocking directorates network. Our query searched for users by name who included one of their associated company names in their Twitter description or included the keywords "vc", "capital", or "partner". This resulted in 1271 matched individuals, whose accuracy was manually verified on a 10% sample and found to be 87.4% accurate. We found that 15% of the interlocking directorates network was composed of VCs, whereas 23% of the Twitter network was composed of VCs. We believe this representation of VCs is reasonably similar, and relatively realistic.

We used Condor to automatically generate the Twitter network. Links in this network exist between a person who has tweeted to another person, or a person who has retweeted another person's tweet. We limited the network construction to only the users' past 100 tweets, which is most representative of an individual's recent tweeting behavior. Due to technical limitations, we could not analyze more than 100 tweets in the user's history. This produced a network of 45,521 nodes and 168,326 links. We analyzed the Twitter network using standard centrality algorithms including betweenness, degree, closeness, and reach-2. Reach-2 is a relatively new centrality metric, which indicates the number of nodes the ego can reach in 2 steps.

3.2 Startup Success Metrics

We defined three metrics as the dependent variables with which to evaluate startup success. Foremost, we collected information about the total amount of funding (venture capital or otherwise) that the startup has received since its founding using Crunchbase (www.crunchbase.com). Secondly, we collected information about the startup's annual sales from OneSource (www.onesource.com). We found total funding information for 1514 of the startups extracted from Capital IQ, and annual sales information for 525 of these startups. Finally, we defined our third success metric as return-on-investment, or annual sales / total startup funding. This is effectively a measure of the efficacy of a startup in transforming dollars of investment into revenue. We consider these three success metrics separately, however we did observe a positive correlation between startup funding and annual sales ($c=0.51$, $p= 1.17E-36$, $n=525$). We observed no significant correlation between ROI and total funding.

Note that one of the fundamental challenges of conducting this kind of study is not only in determining a good metric of startup success, but also acquiring accurate data. We acknowledge that our metric choices (startup funding, annual sales, and return-on-investment) are not absolute measures of startup success, yet we are confident in the accuracy of our data and we are also confident that they at least partially reflect overall startup success in a meaningful way.

4 Results

Using the dataset previously described, we conducted an analysis to measure the impact of VC networks on startup success. We discuss a number of research questions.

4.1 VCs in the Formal Interlocking Directorates Network

Foremost, in order for us to make any conclusions regarding startup success, we needed to locate successful startups within our networks. Therefore, we investigated the question: are more successful startups more centrally located in the interlocking directorates network?

To answer this question, we looked for correlations between the various centrality measures and our three dependent variables (funding, annual revenue, and ROI). We observed strong positive correlations between total funding and annual sales and all three centrality measures (see Table 1).

Table 1. Correlations between centrality measures and funding & sales in formal network

	n	r: Log of Total Funding	n	r: Log of Annual Sales
Betweenness	1514	0.217**	525	0.232**
Degree	1514	0.312**	525	0.298**
Closeness	1514	0.220**	525	0.197**

** for $p < 0.001$

Startups central in the interlocking directorates network have board members who are highly connected, likely highly connected venture capitalists sitting on multiple boards. We tested this hypothesis using a standard Pearson's t-test and did indeed find VCs to be more central than non-VCs in our network (see Table 2).

Table 2. T-Tests on formal network centrality measures: VCs vs. Non-VCs

	mean for VCs	mean for Non-VCs	n	p-value
Mean Betweenness Centrality	1662.56	149.80	7350	9.13e-11
Mean Degree Centrality	3.40	2.87	1124	6.79e-09

VCs not only have on average more connections, but also much higher betweenness centrality than non-VCs. Combined with our earlier observation regarding successful startups being more centrally located, we therefore made the hypothesis that the more VCs on a startup's board, the more successful the startup in terms of total funding and sales. Indeed, we found positive correlations between VC board membership and total funding (c=0.29, p=6.02E-12, n=525) and

between annual sales (c=0.21, p=1.99E-06, n=525). This is not surprising, as venture capital firms that invest in startups often negotiate for board representation, so a correlation between total funding and VC board membership is to be expected.

We then looked at VC board membership and ROI, defined as the ratio of revenue to funding. Surprisingly, we observed a negative correlation between board membership and ROI (c=-0.10, p=0.02, n=525). We verified these results with a Welch Two Sample t-test, where we broke the dataset into two groups: startups with VCs on their board, and startups without. All t-tests proved statistically significant with $p<0.005$. We found that startups with VCs on their board earn on average $6.81M more annually in revenue than startups without VCs on their board, and receive $15.7M more in funding. However, startups without VCs conclusively experience higher ROI, on average 191% higher than startups with VCs. When sorted by ROI, the top 20% of startups have on average 18% VC board membership, whereas the bottom 20% of startups have on average 31% VC board membership. This is statistically significant (t-test p=0.0037, n=525).

4.2 VCs in the Informal Twitter Social Network

We now turn to an analysis of the informal network, the Twitter network, as we hypothesized that by analyzing a different, more informal, network of communication, we would likely reach new insights regarding the influence of VCs on the success of startups.

We began our analysis by first comparing the formal network with the informal network, as both networks are composed of the same people. Interestingly, we found little to no statistically significant correlations between these two networks, neither in terms of centrality measures nor in terms of overlap of core individuals (only 3 people were among the most central in the top 100 of both networks ranked by betweenness centrality and degree centrality). These top three individuals (Jon Sakoda: New Enterprise Associates, Roger Lee: Battery Ventures, Peter Levine: Andreessen Horowitz LLC) are all venture capitalists with a long history in the tech startup industry, sit on 12 or more boards (as compared to the average number of boards someone sits on in our dataset which is 3.92) and have an above-median number of Twitter followers.

Our comparison of the formal network with the informal network demonstrated that the two are very different networks, with no clear correlation between individuals' position within each. That said, in our continued attempt to ascertain the influence of venture capitalists on the success of startups, we reasoned that an investigation of venture capitalists' behavior and location in the Twitter network would inform our understanding of their communication patterns and influence on startup success.

From our previous study, we found venture capitalists to be centrally located in the interlocking directorates network. This held true for our smaller network composed of only the 1271 people we found Twitter usernames for. We expected venture capitalists to be centrally located in the Twitter network as well.

Using a two-tailed unequal variance t-test, we observed VCs are indeed more central in the Twitter network. We measured statistically significant differences in a number of centrality measures among VCs and non-VCs, with the VC group consistently more central than the non-VC group (see Table 3).

Table 3. T-Tests on formal & informal network centrality measures: VCs vs. Non-VCs

n = 1271	p-value T-Test	Mean for VCs	Mean for non-VCs
Betweenness (ID network)	4.19E-06	4299	6145
Degree (ID network)	2.44E-07	4.34	3.05
Closeness (ID network)	4.78E-16	0.0001	0.0001
Betweenness (Twitter network)	0.012	2243375	1980370
Closeness (Twitter network)	0.029	0.0036	0.0035
Degree (Twitter network)	0.011	65.8	60.2
Reach-2 (Twitter network)	2.49E-07	918	670

ID network: Interlocking Directorates network

Given our observation that VCs are more central in the Twitter network, we were curious to determine what about their Twitter behavior - and by extension their communication behavior - influenced their network centrality.

We conducted t-tests between VCs and non-VCs on a number of Twitter usage characteristics, including the number of followers the user has, the number of public lists the user is on, the number of tweets the user has made, and the number of people the user is following. To prevent distortion from outliers with very many and very few followers, we performed our analysis on a truncated mean dataset sample (we sorted the dataset by number of followers, and removed the top and bottom 5%). As a measure of the "popularity" of the user, we took the ratio of the number of users the person is following to number of followers the user has. The lower this number, the more followers the user has in proportion to the number of users the user is following, and thus the more "popular" the user on twitter.

The results of this analysis are provided in Table 4. Generally, we discovered that VCs truly are more "popular" than non-VCs (the popularity ratio differs by 23% between the two groups, with a t-test significance of 0.012). Furthermore, VCs have 22% more followers than non-VCs (although this result only has a statistical significance of 0.077). Additionally, VCs appear on 31% more public lists than non-VCs.

VCs appear to have greater social capital on Twitter than non-VCs. Interestingly, VCs tend to tweet less than non-VCs (VCs post & repost 38% less than non-VCs). However, they have a strikingly higher Twitter popularity ratio as compared to non-VCs (a higher ratio indicates lower popularity). This means that VCs truly do - at least in the digital social networking space - have a higher social capital than non-VCs.

Table 4. T-Tests on Twitter characteristics: VCs vs. Non-VCs

Description	T-test	Mean (VCs)	Mean (non-VCs)
The number of followers this account currently has	0.0773	4032	3302
The number of public lists that this user is a member of	0.0127	194	149
The number of tweets (including retweets) issued by the user	0.0004	1845	2963
The number of users this account is following	0.3864	794	681
Twitter popularity (# following / # followers) [Lower number is more popular]	0.0119	0.454	0.588

4.3 Network Centrality and Financial Success

These results lead us to the conclusion that VCs are truly popular people - guardians not only of money but also social status and information. Clearly, this bears implications on the success of the startups they fund and sit on the boards of. To this end, we wondered if we could determine a correlation between centrality in the Twitter social network and some measure of financial success - either their personal income and/or the funding of the startup(s) they are affiliated with.

4.3.1 Network Centrality and Income

Foremost, we investigated the correlation between an individual's' position in the network and their income, as measured by the average income of their residential zip code (we extracted this data from the public US IRS dataset from 2014[2]). We looked at both the formal and informal networks. We found that generally, the more central someone is located in either the formal or informal network, the higher his or her income. This was especially true with the measure of 0-2 in the Twitter network ($r = 0.14$, $P = 0.000$).

Table 5. Correlations between network centrality measures and someone's income

Correlation with	Log of Average Income	
n=1172	r	P
Betweenness (Twitter network)	0.079**	0.005
Closeness (Twitter network)	0.038	0.173
Degree (Twitter network)	0.079**	0.005
Reach-2 (Twitter network)	0.145**	0.000
Betweenness centrality (ID network)	-0.012	0.670

[2] https://www.irs.gov/uac/soi-tax-stats-individual-income-tax-statistics-2014-zip-code-data-soi

Degree centrality (ID network)	0.053	0.061
Closeness centrality (ID network)	0.066*	0.018

** for p<0.01 ID network: Interlocking Directorates network
* for p<0.05

This would imply that VCs, who are generally more central in both networks, tend to have greater income. That said, we did not find a statistically significant difference in income between VCs and non-VCs (t-test P = 0.25 n=830). Clearly, VCs are not the only individuals in our networks who are generating personal wealth (the entrepreneurs clearly are as well!).

Additionally, from our earlier analysis, we demonstrated that VCs have a significantly higher social capital than non-VCs. We reasoned that perhaps this ratio would correlate with residential income. Indeed, we found just that. We found a significant negative correlation between an individual's' income (on the logarithmic scale) and their ratio of # following / # followers. Because this ratio is inversely proportional to social capital, the greater someone's Twitter social capital, the greater their income (c=-0.105, p=0.00018, n=1172). Therefore, by transitive reasoning, we conclude that VCs are not only socially prominent people, their prominence is rewarded financially.

Our analysis so far enabled us to determine that individual VCs are more central in both the formal and informal networks, which correlates with greater income and a higher social capital.

4.3.2 Network Centrality and Startup Funding

Next, we investigated whether an individual's' position in the Twitter network was indicative of the financial success of the startup to whom that person is affiliated. We hypothesized that those individuals who are more central in the network - those with higher personal income - would be affiliated with more highly funded startups.

The Capital IQ database contained a listing of all the companies each individual is affiliated with - either as a board member or employee. If a person was affiliated with a startup we analyzed in our dataset of 1514 startups (from the formal interlocking directorates network), we had a funding amount for that startup. In total, we found funding information for at least one affiliated company for 830 people in our dataset. Less than 10% of these people were affiliated with another startup for which we had funding data, so we decided an accurate and comparable measure would be to take the maximum startup funding of all startups for which we had data for each person. We looked at the correlation between our centrality measures and the log of the maximum affiliated startup funding for the 830 people with such data. We found significant positive correlations between centrality measures and startup funding, as seen in Table 6.

Table 6. Correlations between Twitter centrality measures and someone's max startup funding

Twitter network	n=830	r: Log of startup funding	p
Betweenness Centrality		0.098	0.005
Closeness Centrality		0.063	0.070
Degree Centrality		0.109	0.002
Reach-2 Centrality		0.244	0.000

All centrality measures except closeness exhibit a significant positive correlation with their max affiliated startup funding. Interestingly, reach-2 displays the largest correlation, at 0.24. A possible explanation for this is that in real life, people are very likely to share leads and opportunities with their close friends (1 degree) and their friends of friends (2 degree). Degree is correlated (at 0.109) with funding, but significantly less correlated than reach-2 (which is 0.24). We reason that degree is less strongly correlated than reach-2 because people really do use their friends-of-friends network and don't depend merely on their closest contacts. Using simply degree to indicate funding misses out on the real-world events that happen due to friends-of-friends. Thus, the friends-of-friends network (reach-2) is really a much better representation of how information and opportunities spread throughout the network. It's not who you know that counts, it's who your friends know. This finding is supported by the academic world; in fact, the strength of weak ties (indirect connections, or friends-of-friends) was first presented in Granovetter's seminal work "The Strength of Weak Ties" (1973). With over 40,000 references to date, Granovetter's work explains the prevalence of weak ties and their efficacy in a variety of personal and professional contexts. Our research appears to affirm that the VC-startup context is yet another domain where weak ties dominate.

5 Discussion

We've conclusively demonstrated that more VCs on a startup's board correlates with more funding. This is reasonable, because when VCs commit funding to a startup, it is in their best interest to support that startup's success, not just financially but also by providing advice and opportunities. VCs often request a board seat to gain authority over the startup, and potentially influence decisions that will yield the greatest return on the VC's investment.

We've also conclusively demonstrated that more VCs on a startup's board correlates with greater sales revenue. There are a variety of explanations for such a correlation. Foremost, startup funding amount and sales amount are correlated, which is logical. The more funding the startup receives, the more resources it has to generate revenue. Additionally, receiving funding from venture capital investors is an indication that external parties place trust in the startup and expect a return on their investment, so it is logical to expect such startups to generate greater sales revenue.

Our result indicating that VC board membership correlates negatively with ROI is somewhat surprising. Certainly, our analysis does not enable us to make any claims regarding causation, so we are careful not to reach conclusions that make any causal claims between VC participation and ROI. That said, the presence of the correlation is intriguing and we therefore provide the following discussion of how to interpret this result.

From the startup's perspective, startup funding is not free money, but rather money that is traded for company equity and potentially decision-making power. The more funding a startup receives, the less equity the founders and employees themselves get to keep. Company sales, however, represent money being generated by the company that contributes to a company's valuation. A higher ROI ratio (sales / funding) indicates that the value generated by the startup itself - the founders and the employees - is likely to stay within the startup and not be diluted by external investors such as VCs who "purchased" equity via investment. From the startup's perspective, a low ROI indicates that the startup has taken on a substantial amount of funding but not seen a relative level of sales. We have shown that low ROI correlates with a greater percentage of VCs on a startup's board. It is likely that in this early stage of startup creation, more VCs invest in a startup and gain board membership, yet the cash they pump into the company in the form of investment is not matched in terms of startup revenue generated.

This is a disappointing realization, especially since VCs typically invest in startups with high growth potential. They expect a rapid return on their investment, and will typically do what it takes to direct a startup down this path to rapid growth. That said, it is well known that venture capitalists invest in a large suite of portfolio startups with the hope of just a small percentage yielding massive returns. According to Dave McClure, a partner at the VC Firm 500 Startups, 50-80% of startups yield no exit or return. 15-25% yield a small return of 2-5x. 5-10% of investments might reach a valuation of $100 million with exits yielding 10-20x. And unicorns are, of course, extremely rare (<1% reach $1 billion valuations returning 50x or more). In summary, McClure concludes that "…most startup investments fail, a few work out ok, and a very tiny few succeed beyond our wildest dreams." (McClure 2015). Perhaps this is simply the innate process of VC funding, and our data analysis exposes the inefficiencies of the system.

On the other hand, startups with high ROI seem to have less VC members on their board. These startups likely did not receive high amounts of funding, yet are generating a disproportionately large amount of sales. Because they did not receive a large amount of startup funding, they were not in a position to need to accept VCs onto their board. This does seem to lead to the logical conclusion that startups without VCs - and therefore without VC funding - seem to do better in terms of ROI, at least in the first 5 years. This concept has been written about numerous times in a number of entrepreneurship blogs and articles, with the underlying recommendation (as one article put it) "If you are looking towards more measured growth for your startup, want to keep control or you're simply not

established yet, you probably want to avoid VCs" (Jee 2016). The evidence certainly seems to indicate the avoidance of VC investment, if possible.

6 Limitations & Suggestions for Future Work

6.1 Demonstrating Causality

One of the fundamental limitations of our work is that our dataset included no temporal data, and thus we were unable to investigate cause-and-effect relationships. We were merely able to observe statistically significant correlations, and hypothesize about these correlations under the assumption that they may indeed be related via causality. Having dependent variable data (startup funding and startup revenue) over time would have facilitated a causal analysis. An interesting question to investigate would be to analyze ROI over the lifetime of a startup, and relate this to VC board participation. Our expectation would be that ROI would increase as VCs became less present on the board over time. Turning to the informal network, it would be interesting to analyze the social network behavior of VCs vs. non-VCs over time, and relate this to the performance of the startups they are involved with. One would expect VCs to gain popularity on Twitter as they become more central in the formal network - and thus become involved with more highly funded startups.

6.2 Revealing Real-World Communication Patterns

The two communication networks we analyzed in this work (interlocking directorates and twitter) were only proxies for the real-world communication that we assume occurs between VCs and entrepreneurs. Although we acknowledge our choice of networks as a limitation, we argue that both networks do reflect to some reasonable degree of accuracy the presence of communication between two individuals. With the interlocking directorates network, we know that board members meet annually and therefore have the opportunity to exchange information. Via the twitter network, we know that if two people have exchanged tweets or retweeted the same tweet, they have exchanged information. However, our results indicate little overlap in individual centrality between the two networks. This may indicate that the communication captured between these two networks is of a very different nature. Fundamentally, we cannot claim that the information exchanged in either network is strictly related to the status or success of the startup in which the individual is engaged. It is likely that the twitter

network captures much "noisier" communications (non-professional communications) whereas the interlocking directorates network is more representative of professional communications. This may explain our observation of little overlap between the two networks. However, we are unable to know for sure.

An interesting possibility for future work would be to construct a communication network among the individuals in our network which is actually representative of the real-world, pertinent information that is communicated. Such a network could be constructed by conducting a survey of the individuals in our networks, requesting them to respond to information about their communication patterns on a weekly basis (to whom did they converse, what was the nature of the conversation (business, personal, etc.) By constructing a third network based on this data, we believe we could develop intriguing insights by comparing to our formal and informal networks.

6. 3 More Advanced Analytics

We acknowledge that our analysis could be strengthened by building a multiple regression model to predict startups' success. This is intended as a suggestion for future work. Furthermore, in building such a model, it would be interesting to control for additional variables present in our dataset, such as gender, VC/startup geographic location, professional status, income bracket, and/or board membership role.

7 Contributions & Conclusion

7. 1 Contributions

In this work, we make the following contributions:

1. Demonstrate a novel approach to studying startup success by creating and comparing formal and informal networks based on startup board of director membership.

2. Collect a substantial dataset from multiple sources (Capital IQ, Crunchbase, OneSource, US Tax Data) which did not previously exist and which permitted investigation of questions not previously analyzed in this way.

Given our analysis of this dataset, we provide evidence for the following conclusions:

1. Startups and individuals located more centrally in both the formal and informal network are generally more successful - in terms of startup funding, revenue, Twitter popularity and personal income.

2. Startups with more VCs on their board tend to receive greater funding, have greater annual sales, but a smaller return-on-investment (defined as revenue funding).

3. VCs are significantly more central in both formal and informal networks than non-VCs, and they have greater popularity (defined as ratio of followers to number of people you follow on Twitter). Interestingly, VCs tweet significantly less than non-VCs, further proving the point VCs are inherently more "popular" than non-VCs.

4. We found little overlap between the interlocking directorates network and the twitter communication network, indicating that these are two rather distinct communication networks despite the fact that centrality in both networks is an indicator of success - both startup success and personal success.

7.2 Conclusion

In our study of the influence of venture capitalists via formal and informal networks, we have determined that VCs play a central role in the success of a startup. Our work reveals intriguing comparisons between two distinct communication networks - one composed of startup board membership and another composed of twitter social networks. From our analysis, it is clear that VCs can be considered the keepers of funding and information, and therefore hold considerable power and influence in the tech startup ecosystem.

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