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RESEARCH PAPER

Textual sentiment analysis and description characteristics in crowdfunding success: The case of cybersecurity and IoT industries

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Abstract
Crowdfunding platforms offer entrepreneurs the opportunity to evaluate their technologies, validate their market, and raise funding. Such platforms also provide technologies with an opportunity to rapidly transition from research to market, which is especially crucial in fast-changing industries. In this study, we investigated how the sentiments expressed in the text of the project campaigns and project characteristics influence the success of crowdfunding in innovative industries such as cybersecurity and the Internet of Things (IoT). We examined 657 cybersecurity and Internet of Things (IoT) projects between 2010 and 2020 that were promoted on Kickstarter and IndieGoGo, two rewards-based crowdfunding platforms. We extracted technological topic attributes that may influence project success and measured the sentiments of project descriptions using a Valence Aware Dictionary and sEntiment Reasoner (VADER) model. We found that the sentiment of the description and the textual topic characteristics are associated with the success of funding campaigns for cybersecurity and IoT projects.

Keywords Crowdfunding · Cybersecurity · Internet of Things · IoT · Sentiment analysis

JEL Classification D26 · D82 · G32 · L26

Introduction

Online crowdfunding is a relatively new form of financing for projects, people, and businesses that has received considerable attention from both academics and practitioners in the last decade (Belleflamme et al., 2014; Mollick, 2014). The crowdfunding model enables a large number of people to contribute small amounts of money to projects in the hope of achieving a combined total amount that meets or surpasses a predetermined funding target that was decided by the project. Crowdfunding has its roots in the creative industries, where it was successfully pioneered in the financing of albums and concerts (Gamble et al., 2017). Schwienbacher and Larralde (2010) define crowdfunding as an open call for the provision of financial resources either in the form of donations or in exchange for some form of reward or voting rights to support initiatives for specific purposes. Mollick (2014) defines crowdfunding as "the efforts by entrepreneurial individuals and groups – cultural, social, and for-profit – to fund their ventures by drawing on relatively small contributions from a relatively large number of individuals using the internet, without standard financial intermediaries."

Crowdfunding has grown exponentially in recent years and is expected to reach a market size of $28.8 billion by 2025. The concept of crowdfunding is rooted in the broader concept of crowdsourcing, which develops activities using the ideas, feedback, and solutions sourced from the "crowd" (Belleflamme et al., 2014). The objective of crowdfunding is to raise funding from the general public who can then

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participate in strategic decisions or may even have voting rights, e.g., in the case of equity crowdfunding (Lambert & Schwienbacher, 2010). During initial concepts and seed phases, companies can use donations and rewards-based crowdfunding (Best et al., 2013; Rossi, 2014), which became popular thanks to platforms like IndieGoGo in 2008 and Kickstarter in 2009 (Agrawal et al., 2014; Ahlers et al., 2015; Belleflamme et al., 2014; Mollick, 2014; Zhang & Chen, 2019). During the period of planning, development, business launch, and early growth, crowdfunding may bridge the gap to later capital needs in the future, such as expansions, where traditional forms of financing, like business angels and venture capital funds, are available.

Sentiment and textual analysis have been used by researchers to investigate how emotions and sentiments expressed in pitches of entrepreneurs may influence crowdfunding fundraising success, providing contradicting results (Mochkabadi & Volkmann, 2020; Wang et al., 2017, 2018). Further, previous research on the dynamics of crowdfunding did not distinguish between industries (Mollick, 2014). The objective of this paper is to investigate how the sentiment of text in project campaigns, and project topic characteristics, influence crowdfunding success in innovative industries. We focus on projects in the fields of cybersecurity and IoT, as those present high risks in terms of being disrupted or becoming obsolete (Jensen & Özkil, 2018; Moore, 2010; Zhu et al., 2021). Backers face high information asymmetries with respect to evaluating the underlying science of such technologies, as well as the market opportunities available to them. Determining which new crowdfunding projects are likely to be successful is a challenging task that may require specialized knowledge from the investors. Potential investors in such projects may be more prone to sentiments and emotions to compensate for the challenges associated with the novelty of the technologies and the lack of specialized knowledge. The fundamental uniqueness of cybersecurity and IoT projects within a crowdfunding environment is that they rely on the crowd, rather than technology experts, who are arguably less equipped to make educated investment decisions due to a lack of specialized knowledge. It is therefore unclear whether innovative and unconventional projects, such as cybersecurity and IoT projects, are well-positioned to leverage crowdfunding advantages compared to other, more conventional sectors.

In this study, we examined campaigns listed on the Kickstarter and IndieGoGo platforms between 2010 and 2020. Both platforms are based in the USA but serve entrepreneurs from across the world who engage in fundraising campaigns. We identified 657 campaigns that involve cybersecurity and IoT-related projects. The goals of this study are to investigate how the sentiments derived from the text used in the description of crowdfunding campaigns relate to funding success and to examine whether specific technology topics used by cybersecurity projects may influence campaign success.

We, therefore, make the following contributions. First, we show how the sentiment of the description of cybersecurity and IoT projects affects the campaigns' success. Second, we demonstrate how the text embedded in the project campaigns, created by the entrepreneurs to identify specific technological topics, is associated with campaign success. Third, we examine whether previous research findings on the drivers of success in crowdfunding generally also hold for projects in the cybersecurity and IoT sectors, even though these sectors require specialized knowledge from investors. Lastly, we contribute to the literature on the arguably under-researched intersection of entrepreneurial finance and specialized projects. The results of this study will benefit technology professionals, potential investors, and companies operating in cybersecurity- and IoT-related technologies.

This study is structured as follows: The second and third sections review the academic literature related to sentiment analysis in crowdfunding research. The fourth section describes the research methodology and data sources. The fifth section presents the results of the analysis. The sixth section discusses key findings and practical implications. The seventh section presents the limitations of the study and provides areas for future research.

Literature background

Crowdfunding dynamics and campaign success

Venture capital scholars have provided an extensive list of factors that lead to successful company fundraising (Baum & Silverman, 2004; Shane & Stuart, 2002). In this case, potential signals of quality play an important role in investors' decisions (Spence, 1978). In the context of crowdfunding, previous research identified several quality signals that lead to the success of crowdfunding campaigns (Ahlers et al., 2015). Many projects lack various types of professional quality aspects, which might be the reason why so many projects do not reach their funding goal (Mochkabadi & Volkmann, 2020). Mollick (2014) analyzed Kickstarter campaigns and found that personal networks and project quality are associated with the success of crowdfunding efforts. In addition, longer duration of the campaign decreases the chances of success (Cumming et al., 2017; Mollick, 2014; Song et al., 2019), possibly because a long campaign is a sign for lack of confidence (Mollick, 2014). However, Zheng et al. (2014) found the opposite is true on Chinese reward-crowdfunding platforms, where the duration of the campaign is positively associated with success.

Promotion by the platform is strongly associated with success (Song et al., 2019), and therefore, projects promoted by a crowdfunding platform, such as Kickstarter's Staff Picks or Projects We Love, are more likely to succeed.

Signals such as videos and frequent updates are associated with greater success, and spelling errors reduce the chance of success (Jensen & Özkil, 2018; Wu et al., 2024; Zhang et al., 2023). Cumming et al. (2017) found that the success of cleantech crowdfunding projects likely depends on the number of photos in their gallery, the presence of video pitches, and the length and quality of the project description.

In the case of equity crowdfunding, where investors receive a stake in the company in exchange for their financial support, Hakenes and Schlegel (2014) found that high funding goals may provide backers with a sense of security as their investment will only go through if enough other people will also choose to back the campaign, which implies that a higher level of due diligence will be performed. However, in the case of reward crowdfunding, which offers backers non-monetary, often tangible rewards in return for their pledges, such as products or experiences, several researchers suggest that higher funding goals lead to lower chances of success (Cumming et al., 2017; Jolliffe, 2002; Mollick, 2014; Zheng et al., 2014). In addition, Belleflamme et al. (2014) found that smaller targets are preferable in rewards-based campaigns and larger targets in equity crowdfunding.

Belleflamme et al. (2014) also found that companies that offer products are more successful in achieving their funding goals than those offering services, mainly due to the inherent preference of people to invest in tangible outcomes which are perceived as more certain. Furthermore, Härkönen (2014) suggests that the success of a crowdfunding campaign can be attributed to the ability of the crowd to easily understand the promoted product. In this case, the information provided in the description of the crowdfunding pitch is of particular importance. Following the work of Belleflamme et al. (2014), this work distinguishes between software and hardware projects to test whether the "tangibility" of a project also plays a role in the success of a campaign.

Akerlof (1970) described the asymmetry of information using the example of used car sales, where the seller usually has better information on the product. In crowdfunding, the entrepreneur knows more about the project than the investors, which creates uncertainty that is further intensified in the case of projects that also require specialized knowledge. A large number of projects and investors involved in crowdfunding platforms offer a unique learning environment to study the information asymmetries when new technologies are involved and the value of mechanisms on crowdfunding platforms to mitigate such asymmetries (Cumming et al., 2017).

Cybersecurity and IoT

There is no consensual definition of cybersecurity, as it is a broadly used term with highly variable definitions, often subjective, and at times uninformative (Craigen et al., 2014). The International Telecommunication Union defines cybersecurity as "the collection of tools, policies, security concepts, security safeguards, guidelines, risk management approaches, actions, training, best practices, assurance and technologies that can be used to protect the cyber environment and organization and user's assets" (International Telecommunication Union, 2009; ITU, 2009). Craigen et al. (2014) define cybersecurity as "the organization and collection of resources, processes, and structures used to protect cyberspace and cyberspace-enabled systems from occurrences that misalign de jure from de facto property rights." Most definitions emphasize the multidimensional nature of cybersecurity and its relation to organizational, economic, political, and other human dimensions (Goodall et al., 2009).

The Internet of Things (IoT) describes the network of physical objects, i.e., "things," embedded with sensors, software, and other technologies for the purpose of communicating and exchanging data with other devices and systems over the internet. IoT projects are on the rise as a result of the progress in digitization and its positive effect on firms' performance (Viktora-Jones et al., 2024) and as being an important element in digital transformation. IoT projects can be based on software or hardware, where cybersecurity could be a subcategory of IoT (Sorri et al., 2022).

Although the importance of companies in the fields of cybersecurity and IoT is enormous today, those companies face several challenges, such as increased legal and industry competition risks, that differentiate them from conventional companies that raise funding from private investors (Zhu et al., 2021). Jensen and Özkil (2018) identified challenges in crowdfunded technology product development, that could result in the failure of the crowdfunding campaign. In addition, Molling and Zanela Klein (2022) found that companies struggle to understand the potential and limitations of IoT to generate appropriate value propositions for their IoT products and services. Crowdfunding platforms such as Kickstarter and IndieGoGo offer a fast transition from research and development to the market, and examining the dynamics of crowdfunding in the IoT and cybersecurity industries is therefore of great importance.

Textual and sentiment analysis in crowdfunding research: hypotheses development

Mochkabadi and Volkmann (2020) argue that there is great potential in analyzing how the language used in updates and project proposals relates to campaign success. Previous research used textual analysis to identify the role of a project's description in the success of the campaign.

Sentiment is usually related to the self-confidence of the author, where authors with high confidence are more likely to create positive text (Wang et al., 2017). Research on Peer-to-Peer (P2P) lending shows that overly confident borrowers may not be able to repay their loans in time (Gao & Lin, 2015) indicating that the sentimental effect may not lead to positive outcomes.

Previous research identified two broad categories regarding textual analysis: readability and tone (Dority et al., 2021). Several proxies have been used for readability, including word count, language complexity, spelling and grammatical errors, and more. The relation between the length of the pitch and the funding success is not clear. Several studies found a positive relationship between the number of words in the pitch and funding success (Cumming et al., 2017; Zhou et al., 2018), meaning that a more detailed and longer description increases the success rate. However, other studies found a negative relationship (Horvát et al., 2018) or a U-shaped relationship (Nowak et al., 2018). To contribute to this debate, we also investigated the length of the title and the description of the projects.

The Flesch-Kincaid readability tests are designed to indicate how difficult a text in English is to understand and are commonly used to assess the readability level of text. These tests assess the difficulty of reading the given text based on several constants and the number of words, sentences, and syllables, as well as the grade a reader needs to be to be able to understand it. Block et al. (2018) used the Flesch Readability Index to measure the language complexity of campaign updates. They found that updates with simpler language significantly increased the number of investments made during the campaign. Simpson's Diversity Index is a measure used to quantify the diversity or richness of species within a community, taking into account both the number of different species present and their relative abundance. To investigate the impact of readability on funding success, Nowak et al. (2018) used Simpson's Diversity Index to measure the diversity of the languages used in the description of a loan. The Linguistic Inquiry and Word Count (LIWC) is a text analysis tool that quantifies the presence of psychologically meaningful categories in a language, providing insights into the psychological and emotional content of texts. Horvát et al. (2018) used the Linguistic Inquiry and Word Count dictionary model. These studies found that higher counts of different words, punctuation, prepositions, and adjectives result in higher funding success.

Dority et al. (2021) examined the impact of the language used in the campaign description on campaign success, and specifically for Title II equity-based crowdfunding. They examined the campaign descriptions and focused on tone and two aspects of readability: information quantity — the amount of information available to the investor, and information quality — the ease of understanding of the passage of text. Overall, the results indicate an inverted U-shaped relationship between information quantity, information quality, and tone and Title II equity crowdfunding campaign success.

To capture the tone of the crowdfunding campaign, previous research used sentiment analysis to identify how the sentiment of the project description may impact the success of crowdfunding campaigns. When humans approach text, they use inferences to determine the tone of the text, such as whether it is positive or negative. The inferences ultimately impact how the reader feels about a certain text and can have a significant impact on the decisions they make (Dority et al., 2021). The limited research on the impact of textual tone on funding success shows mixed patterns across different types of crowdfunding. For instance, Horvát et al. (2018) examined equity crowdfunding and found that negative emotions in the pitch are positively associated with funding probability. On the other hand, Wang et al. (2017) found that strong positive sentiment is associated with successful reward crowdfunding campaigns.

Uparna and Bingham (2022) studied over 30,000 entrepreneurial loan requests from one of the largest loan marketplaces to understand how the sentiment in text-only pitches to investors affects fundraising. They found that pitches with negative sentiment are funded faster than those with positive sentiment, and that pitches with negative sentiment result in lower interest rates for entrepreneurs and fewer defaults. Peng et al. (2022) analyzed donation data to investigate how individuals' donation behavior is affected by previous donation amounts and the information provided by the fundraising platform. They found that positive sentiment in the messages left by donors does not affect subsequent donation amounts.

Several papers investigated rewards-based crowdfunding project success using sentiment analysis. Li et al. (2022) examined the success determinants of cultural and creative crowdfunding (CCCF) projects using Natural Language Processing (NLP) to calculate the sentiment and information entropy of reviews in crowdfunding projects. They found a positive influence of peer review valence in CCCF projects on crowdfunding success. Valence indicates the average sentiment valence of all reviews of a crowdfunding project. Wang et al. (2022a) used sentiment analysis and paired sample *t*-tests to examine differences in crowdfunding campaigns before and after the COVID-19 outbreak in March 2020. Their findings suggest that sad emotions were significant in the description of campaigns following the COVID-19 outbreak.

Wang et al. (2022b) investigated information distortion in investment decision-making within the crowdfunding market. They discovered that a more detailed project description with a positive sentiment, encourages investors to invest in

the project. Based on the results of these studies and the assumption that crowdfunding investors may be particularly susceptible to sentiment in emerging and specialized industries, we expect that sentiments derived from textual analysis will also play a role in cybersecurity and IoT crowdfunding success. Crowdfunding success is defined and evaluated by three metrics in this research. Further details can be seen in the methodology section. We therefore formulated the following hypothesis:

Hypothesis 1: A project description with a positive sentiment will be positively associated with the project's success.

Horvát et al. (2018) analyzed United Kingdom equity crowdfunding data and focused primarily on the text associated with each campaign. They utilized the Linguistic Inquiry and Word Count dictionary to investigate stylistic aspects of the language and identify elements of the language that are associated with success, regardless of the type or sector of a venture. Latent Dirichlet Allocation was used by Horvát et al. (2018) to model the topics within campaign descriptions, revealing that the description of an equity crowdfunding campaign can significantly affect fundraising success. The extent to which campaigns are spread across topics was measured using entropy. Low entropy represents certainty and high entropy represents uncertainty. Horvát et al. (2018) found that the novelty of a campaign, as measured by the topic entropy of the text description, is negatively correlated with success: campaigns that are easily categorized into a few coherent topics are significantly more successful than their counterparts with a diversity of topics. For example, a topic consisting of student, school, education, and university, is coherent. On the other hand, a topic consisting of film, bank, stove, and sport, is incoherent. This result holds even after controlling for writing quality and style, as well as a suite of variables previously identified by other studies to impact success. Adding to these results the challenges faced by many companies in crafting clear and compelling value propositions for IoT products and services (Molling & Zanela Klein, 2022), alongside the general lack of understanding among audiences regarding IoT projects and services (Kumar et al., 2019), we also expect that topics identified in textual analysis, which are not easily understood by the crowd, may negatively influence crowdfunding fundraising success in this industry. We therefore hypothesize that:

Hypothesis 2: A project description that involves cybersecurity and IoT technological topics will be negatively associated with crowdfunding project success.

Method

Context of the study

The cybersecurity industry is growing rapidly, with entrepreneurs constantly starting up new technological businesses around the world. Market analysts estimate that the global information security market, of which cybersecurity is a part, will grow at a 5-year CAGR of 8.5% to reach $281.7 billion by 2027 (Fortune Business Insights, 2023). The largest cybersecurity IPO so far was CrowdStrike, an AI-powered endpoint security platform that protects corporate networks at vulnerable areas of connection, like laptops and phones. CrowdStrike went public in June 2019 at a $6.7B valuation. The large number of startups established annually may overwhelm market intelligence professionals and investors who try to predict which technologies have the potential to be successful.

Cybersecurity projects have been used as a context for this study for several reasons. First, such projects have a high chance to fundamentally reshape and change the way traditional industries have been working. New technologies, business models, and approaches that challenge the status quo are likely to significantly change the industry landscape, and therefore have the potential to produce high investment returns.

However, at the same time, this type of project is also prone to being disrupted by other competing projects shortly, such as by novel technology that makes the project redundant (Jensen & Özkil, 2018; Zhu et al., 2021). In other words, a slow or inefficient implementation process of new research in market technologies can lead to a good project being undermined by other projects that have transitioned faster but are not necessarily better. First, a swift and successful transition of new research to market technologies is therefore necessary to prevent the project from being undermined. Second, cybersecurity technologies often require uncommon, specialized knowledge, which the crowd does not generally possess, therefore increasing the risk of lower or slower adoption. Third, the available qualified workforce to defend computer systems is not growing fast enough. According to some industry reports, there are more job openings than individuals qualified to fill them (Lewis & Crumpler, 2019), and there will soon be a shortage of cybersecurity professionals (Ventures, 2017). Finally, there is uncertainty regarding the underlying science of cybersecurity since much of the scientific research is funded by organizations or governmental agencies with high levels of confidentiality (Maughan et al., 2013, 2015). This further exacerbates the uncertainty associated with cybersecurity and the information asymmetry faced by investors in general and crowdfunding backers in particular.

Sample and data

New cybersecurity and privacy-related technologies are essential to the security and cyber-resilience of systems and infrastructure. The World Economic Forum defines cyber-resilience as "the ability of systems and organizations to withstand cyber events, measured by the combination of mean time to failure and mean time to recovery" (World Economic Forum, 2012). The use of the term "cyber" encompasses the interdependent network of information technology and includes technological tools such as the internet, telecommunication networks, and computer systems (Gortney, 2016). Artificial intelligence, blockchain technology, and their integration with the IoT enable many potential applications related to cybersecurity and consequently unique opportunities for both entrepreneurs and investors.

In this work, we used a similar methodology to Song et al. (2019). We used data from webrobots.io to compile a dataset of projects from Kickstarter and IndieGoGo. We preprocessed the data and removed all duplicate entries of projects that appeared under multiple categories and projects that are not "finished," such as projects that are active, cancelled, or suspended. We included only projects related to cybersecurity or IoT by requiring one or more of the following phrases in the description: "Cybersecurity," "Cyberwarfare," "Secure Coding," "Cyber Threats," "Cyber Privacy," "Blockchain," "Cryptocurrency," "Artificial Intelligence Security," "AI Cyber," "Internet of Things," "IoT," "Web Security," "Network Security," "Information Security," "Internet Security," "Mobile Security," "Firewall," "Antivirus," "Hacker," "Smart Home," and "Raspberry Pi." We manually reviewed the dataset and removed any project that was unrelated to the topic. The final dataset consists of 657 projects, of which 539 are from Kickstarter and 118 are from IndieGoGo.

Model specification

We constructed a model for estimating project success with a common set of relevant control variables. We used the following model (Eq. 1) to test the hypotheses. The dependent variable is project success. Let independent variables be the vector of independent variables, which includes the sentiment index and a set of textual topic variables. Let the project level controls be the vector of the project characteristics variables. Let macro-level control be an economy-wide indicator. The vector of time-fixed effects stands for year dummies. Finally, let be the error term:

$$\begin{aligned} Dependent\ variable &= \alpha + \beta_1 independent\_variables + \beta_2 project\_level\_controls \\ &+ \beta_3 macro\_level\_control + \beta_4\, time\_fixed\_effects + \varepsilon \end{aligned} \tag{1}$$

Dependent variable

Following previous studies, we used three different operationalizations for cybersecurity and IoT project success (Cumming et al., 2017). First, project success was measured by the ratio between the total amount of money raised and the project fundraising goal, denoted as a continuous variable (*funds*). Second, we constructed a binary variable indicating whether the project succeeded in raising the predetermined amount of money in full (*outcome*). The *outcome* variable is based on the Kickstarter "all or nothing" model that indicates if the project fully accomplished its financial goal, i.e., whether it was successful or failed (Cumming et al., 2017). Third, we used the number of backers of each project as a discrete variable (*backers*).

The correlation between the *funds* and the other operationalizations is very low and insignificant ($r = 0.043$ and $r = -0.001$, respectively). The correlation between the *outcome* and *backers* variables is only moderate but significant ($r = 0.337$, p-value < 0.05). These findings support our decision to measure project success using three different metrics, as each metric describes different aspects that are not described by the other metrics.

Independent variables

Sentiment index

Crowdfunding platforms enable entrepreneurs to provide textual information to potential backers to encourage backing for their venture. Therefore, it is important for entrepreneurs to identify and signal certain features of their projects, such as the technologies used and positive sentiment, to influence the investment decisions of backers.

The lexicon-based approach to sentiment analysis uses a predefined dictionary with sentiment labels assignments to words, such that each word is labeled as positive, negative, or neutral. The word sentiment scores are then combined to determine the overall sentiment orientation of the text. We used the lexicon-based approach to determine the sentiment index of the texts in the campaigns and calculate the orientation of a project from the semantic orientation of words or phrases (Ngoc & Yoo, 2014). Previous research that used the lexicon-based approach determined the sentiment by identifying adjectives from the text that correspond with the dictionary of words, and the total sentiment score reflected the polarity of the text (Dorfleitner et al., 2016; Horvát et al., 2018).

We used VADER, a Valence Aware Dictionary and sEntiment Reasoner model, to measure the sentiment index of the description of each cybersecurity and IoT project. The sentiment score ranges from -1 for the most negative

sentiment to + 1 for the most positive sentiment (Hutto & Gilbert, 2014).

Technology textual topic variables

Crowdfunding and other campaigns by firms in sectors with pronounced information problems are more sensitive to soft information (Cumming et al., 2017). The understandability of the concept or offering of a product or service in these sectors is a rather complex feature to measure. Therefore, cybersecurity and IoT projects can be considered at higher risk than projects in more traditional industries, and as such, their application needs to be thoroughly clarified to entice potential backers.

Technological innovations in artificial intelligence, cloud computing, big data analytics, quantum computing, blockchain, and other software and hardware applications ensure that contemporary cybersecurity will remain in flux (Wilner, 2018). IoT is an enabler for the intelligence affixed to several essential features of the modern world, such as homes, hospitals, buildings, transports, and cities. There are many benefits provided by IoT, but it comes with challenges, such as poor management, energy efficiency, identity management, security, and privacy (Yaqoob et al., 2017). Security and privacy are some of the critical issues related to the wide application and adaptation of IoT (Burhan et al., 2018).

In the case of cybersecurity and IoT project campaigns, we expected that certain words included in the project description may influence the decision of potential backers. We therefore mined the descriptions of projects for frequent words related to their technological attributes. We extracted and tokenized the projects description from Kickstarter and IndieGoGo. We preprocessed the texts by converting them to lowercase and removing stop-words and punctuation. To reduce the noise, we then removed words that appeared less than 25 times according to the term's frequency distribution. The process revealed ten textual variables. Since the frequency of each word is relatively low, we created binary technology topic variables by combining keywords of the same subject that represent the technology or the topic of the project. The final ten binary textual variables are: "Software," "Hardware," "DIY" (Do It Yourself), "Raspberry Pi," "IoT," "Blockchain," "Cybersecurity," "Cryptocurrency," "Arduino," and "Smart Home."

Control variables

We included six control variables in the model. First, we controlled for project duration as measured by the number of days between the launch date and the project deadline (*Project Duration*). Second, we controlled for the project title length as measured by the number of characters (*Title Length*). Third, we controlled for the project description length, as measured by the number of characters (*Description Length*). Fourth, a binary variable that takes the value of 1 if the project is from the United States (*USA*) and 0 otherwise, as the project's country of origin may affect the backers' decision. Fifth, since the project success may be affected by the platform, we added a binary variable that takes the value of 0 if the project was on the IndieGoGo website and the value of 1 if the project was on the Kickstarter website (*Platform*). Sixth, we included the NASDAQ seven-day return prior to project launch day, measured as a continuous variable (*Nasdaq Return*), as investment decisions are influenced by macroeconomic conditions in general (Drori et al., 2024), and cybersecurity and IoT venture decisions are impacted in particular by technology sector conditions (Campello & Graham, 2013; Chen et al., 2007).

Estimation approach

As the dependent variable, i.e., the success of the project was measured in three different ways, we used different methods to correspond to the scales and unique features of the variables. We used an Ordinary Least Squares (OLS) regression[1] for the *funds* continuous variable, a logistic regression for the *outcome* binary variable, and a count data model for the *backers* discrete variable. A count data model counts the number of backers for the project. We opted to implement a negative binomial regression model, rather than a Poisson model, because the latter assumes equality between the conditional mean and conditional variance (Cameron & Trivedi, 2013), which does not characterize the distribution of the *backers* variable (mean = 327; variance = 560,228). The post-estimation likelihood-ratio test chi-square of the dispersion parameter alpha in the negative binomial model ($\alpha = 2.326$) significantly indicates that it is greater than zero (chi-squared = 410,000, $p < 0.001$). This result strongly suggests that the dependent variable is overdispersed, thus confirming the choice of a negative binomial model (Xu & Drori, 2023). In addition, we used a Poisson regression model and found a high chi-square statistic, indicating that the Poisson model is inappropriate in this case ($\chi^2 = 762{,}886$, $p < 0.001$).

Results

Table 1 presents the descriptive statistics of different project categories. Most of the projects are categorized as hardware projects (56%), and most originate in the USA (50%).

[1] We implemented the OLS regression because only 9 observations out of 657 have zero values. Since the variable was not zero-inflated, no special treatment is required.

Table 1 Descriptive statistics of different project categories

No	Variables	Total projects	% of total projects	Avg. no. of backers	Avg. amount raised (in $)	No. of successful projects	% of Successful projects
1	Software	110	17%	171	15,082	24	22%
2	Hardware	366	56%	322	40,797	249	68%
3	DIY	174	26%	192	18,220	113	65%
4	Raspberry Pi	297	45%	276	31,226	210	71%
5	IoT	264	40%	356	58,958	145	55%
6	Blockchain	46	7%	74	12,460	14	30%
7	Cybersecurity	100	15%	447	54,811	47	47%
8	Cryptocurrency	32	5%	64	7,431	9	28%
9	Arduino	69	11%	233	22,047	50	72%
10	Smart Home	121	18%	517	101,550	78	64%
11	USA	328	50%	402	55,376	190	58%
12	Platform (Kickstarter)	539	82%	256	28,426	317	59%

Projects belonging to the smart home category, projects belonging to the cybersecurity category, and projects that originate in the USA, attracted the highest average number of backers (517, 447, and 402, respectively). Projects in the Smart Home category, projects in the IoT category, and projects originating in the USA raised the most funds in their campaigns (US$101,550, US$58,958, and US$55,376, respectively). The most successful categories in terms of percentages of projects successfully raising their predetermined goals are Arduino, Raspberry Pi, and Hardware, with 72%, 71%, and 68% success rates, respectively. On the other hand, Software, Cryptocurrency, and Blockchain projects have been the least successful in raising their predetermined goals, with only 22%, 28%, and 30% success rates, respectively.

Correlation matrix and regression results

Table 2 presents the correlation matrix and descriptive statistics for all the researched variables. As the model includes both continuous and binary variables, the correlation matrix reports three different correlation methods. The correlation between two continuous variables was calculated using Pearson's correlation. The correlation between a continuous variable and a binary variable was calculated using point-biserial correlation, which is mathematically equivalent to a Pearson correlation (Sheskin, 2003). The correlation between two binary variables was evaluated using the Phi coefficient (Cohen, 2013). All measurements are on a scale between − 1 for a negative correlation and + 1 for a positive correlation.

Table 3 presents the results for three regression models to predict project success, a model for each operationalization for project success. Model 1 is an OLS regression to predict the success of a project, as measured by the *funds* variable. Model 2 implements logistic regression to predict the project's success using the *outcome* variable. Model 3 uses count data regression (negative binomial) for the *backers* variable to predict the success of projects.

The sentiment index coefficients are positive and significant (p-value < 0.05) across the three models ($\beta = 1.281$, $\beta = 2.752$, $\beta = 0.437$, respectively). The consistent results clearly show that a positive sentiment in the description of a project is associated with its success. Therefore, the empirical results of the three models support Hypothesis 1.

To test Hypothesis 2, we included ten technology textual topic binary variables in the model. We hypothesized that the inclusion of textual topics related to the technology of a project would affect its success. Except for the Hardware variable, all nine other textual variables were found to be significant in at least one of the models. The results therefore indicate that including the Hardware variable in the text does not affect the success of projects. Six of the nine significant topic variables, namely Software, DIY, IoT, Blockchain, Cryptocurrency, and Arduino, were found to have a negative effect on project success in at least one of the three models.

The Software and IoT variables have shown significant and negative effects across the three models, suggesting that including these variables in the descriptions of projects would decrease the likelihood of success, regardless of the operationalization method.

The Smart Home variable is the only textual binary variable that has shown a positive and significant coefficient across all three models. This consistent result suggests that Smart Home projects are appealing to potential backers on Kickstarter and IndieGoGo.

Given that nine of the textual binary variables, i.e., all but the Hardware variable, were found to have significant

Table 2 Correlation matrix and descriptive statistics of research variables

#	Variables	Class	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Funds	DV	C	1																			
2	Outcome	DV	B	0.043	1																		
3	Backers	DV	C	−0.001	0.337*	1																	
4	Sentiment Index	IV	C	0.018	0.057	0.081*	1																
5	Software	IV	B	−0.022	0.330*	−0.093*	−0.040	1															
6	Hardware	IV	B	−0.040	0.224*	−0.007	−0.037	0.502*	1														
7	DIY	IV	B	−0.020	0.082*	−0.108*	−0.083*	0.269*	0.535*	1													
8	Resp-berry Pi	IV	B	0.046	0.231*	−0.061	−0.098*	0.218*	0.446*	0.314*	1												
9	IoT	IV	B	0.045	0.053	0.031	0.167	0.109*	0.043	0.056	0.357*	1											
10	Blockcahin	IV	B	−0.013	0.154*	−0.092*	−0.069	0.324*	0.235*	0.151*	0.201*	0.176*	1										
11	Cybersecurity	IV	B	−0.016	0.095*	0.067	−0.011	0.332*	0.202*	0.139*	0.265*	0.050	0.066	1									
12	Crypto-currency	IV	B	−0.010	0.137*	−0.079*	−0.006	0.182*	0.139*	0.119*	0.162*	0.127*	0.270*	0.056	1								
13	Arduino	IV	B	0.114*	0.099*	−0.042	−0.016	0.127*	0.235*	0.255*	0.177*	0.033	0.094*	0.062	0.077*	1							
14	Smart Home	IV	B	−0.019	0.060	0.120*	0.268*	0.097*	0.058	0.098*	0.171*	0.579*	0.130*	0.004	0.089*	0.085*	1						
15	Project Duration	Control	C	−0.089*	−0.213*	−0.062	−0.029	0.115*	−0.137*	−0.106*	−0.104*	0.085*	0.001	0.078*	−0.002	−0.065	0.090*	1					
16	Title Length	Control	C	0.011	0.211*	0.050	0.036	−0.095*	0.130*	0.037	0.111*	−0.001	−0.084*	−0.064	−0.032	0.132*	−0.022	−0.020	1				
17	Description Length	Control	C	0.031	0.092	−0.044	0.120*	0.051	0.229*	0.149*	0.116*	0.062	0.048	0.088*	0.023	0.213*	−0.086*	−0.062	0.368*	1			
18	USA	Control	B	0.042	0.004	0.100*	0.020	0.033	0.071	0.006	0.117*	0.050	0.024	0.153*	0.056	0.054	0.043	−0.014	−0.102*	−0.025	1		
19	Platform	Control	B	0.018	0.029	−0.200*	−0.056	0.135*	0.428*	0.280*	0.369*	0.029	0.112*	0.076*	0.087*	0.160*	0.176*	−0.092*	0.095*	0.424*	0.024	1	
20	Nasdaq Return	Control	C	0.022	0.052	−0.011	−0.007	−0.022	0.025	0.029	0.060	0.034	−0.120*	0.045	−0.006	−0.048	0.030	−0.032	−0.025	0.001	−0.107*	0.030	1
	Mean			12.881	0.581	327	0.302	0.167	0.557	0.265	0.452	0.402	0.070	0.152	0.049	0.105	0.184	34.307	42.334	#####	0.499	0.820	0.003
	SD			246.438	0.494	748	0.314	0.374	0.497	0.442	0.498	0.491	0.255	0.359	0.215	0.307	0.388	14.230	14.768	27.974	0.500	0.384	0.027
	Min			0	0	0	−0.625	0	0	0	0	0	0	0	0	0	0	1	5	14	0	0	−0.162
	Max			6,316	1	8,456	0.940	1	1	1	1	1	1	1	1	1	1	85	60	135	1	1	0.108

[a]The class column indicates the variable category in the model. DV stands for dependent variable, IV stands for independent variable, and control denotes a control variable

[b]The type column specifies if the variable was captured by a binary (B) measure or by a continuous (C) measure

Table 3 Regression results for project success

Variables/DV (method)	Model 1 Funds (OLS)	Model 2 Outcome (Logit)	Model 3 Backers (Count)
Main exploratory variables			
Sentiment Index	1.281*	2.752***	0.437*
	(0.489)	(0.791)	(0.219)
Textual variables (dummies)			
Software	−1.276***	−3.175**	−1.023***
	(0.282)	(1.003)	(0.243)
Hardware	0.052	0.751	0.287
	(0.508)	(0.609)	(0.217)
DIY	−0.065	−1.868*	−0.449**
	(0.322)	(0.937)	(0.173)
Raspberry Pi	0.976**	1.396^{+}	−0.100
	(0.340)	(0.766)	(0.195)
IoT	−0.583*	−1.371*	−0.563**
	(0.261)	(0.698)	(0.210)
Blockchain	−0.726**	−0.913	−0.427
	(0.247)	(0.991)	(0.349)
Cybersecurity	0.683	0.532	0.448*
	(0.502)	(0.719)	(0.218)
Cryptocurrency	0.550	0.596	−1.185**
	(0.411)	(1.399)	(0.395)
Arduino	−0.712*	−2.150^{+}	−0.208
	(0.273)	(1.106)	(0.227)
Smart Home	0.740^{+}	1.589*	0.453*
	(0.425)	(0.681)	(0.225)
Control variables			
Project duration	−0.030*	−0.072***	−0.008^{+}
	(0.015)	(0.016)	(0.004)
Title length	0.021*	0.056**	0.019***
	(0.011)	(0.018)	(0.005)
Description length	0.003	0.011	0.003
	(0.007)	(0.011)	(0.003)
USA	0.508*	−0.442	0.389**
	(0.250)	(0.487)	(0.131)
Platform	−1.378*	−3.023***	−0.969***
	(0.594)	(0.795)	(0.240)
Nasdaq return	−1.876	−5.604	0.729
	(5.330)	(10.958)	(2.631)
Constant	1.718*	1.425	4.764***
	(0.786)	(1.373)	(0.410)
Year dummies	Included	Included	Included
Observations	657	657	657
F-chi^2	61.62***	79.03***	160.44***
R-squared—pseudo	0.115	0.563	0.019

***p-value ≤ 0.001, **p-value ≤ 0.01, *p-value ≤ 0.05, +p-value ≤ 0.1

coefficients in at least one of the three models, we can conclude that Hypothesis 2 is well supported by the results. The consistent findings indicate that the textual topic description provided by entrepreneurs regarding the technology category is an important factor in project success.

The results further show that some of the control variables also consistently affect all three models. Project duration is negatively and significantly associated with project success, suggesting that, in line with previous findings from Cumming et al. (2017), Mollick (2014), and Song et al. (2019), a longer project duration has a negative effect on the likelihood of achieving success. Similarly, across all three models, the platform on which the project was featured has a significant negative coefficient, indicating that being featured on the Kickstarter platform is related to lower success as compared to being featured on IndieGoGo. In addition, the title length was found to have a significant positive effect across all three models, which means a longer project title leads to higher success rates. The description length and NASDAQ variables were found to have an insignificant effect on the success, regardless of the dependent variable operationalization. Lastly, we found that projects originating in the USA have significantly higher chances of success in terms of the funds raised (Model 1) and the number of backers (Model 3).

Robustness checks

To reinforce the results, we removed outliers by winsorizing the samples in the first and last percentiles and ran the models again. We also estimated Model 3 by using an OLS regression after adding one to the number of backers and then log-transformed it (instead of using a count data model). The results were consistent in both cases.

Discussion

This study examines whether the sentiment and textual characteristics of projects play a role in crowdfunding success for cybersecurity and IoT projects. Ventures have more knowledge about their products, processes, and orientations in comparison to potential backers (Courtney et al., 2017). Backers will therefore consider textual topic features as part of their investment decision process, which ultimately affects the project's success.

The results of this study show that positive sentiment in textual aspects of a campaign is positively associated with project success. These results support Hypothesis 1, according to which the success of cybersecurity and IoT projects is affected by the sentiment of their descriptions. The findings, according to which positive sentiment promotes investment

and negative sentiment discourages investment, are in line with those of Wang et al. (2022b).

Another objective of this study was to investigate whether specific technological topics used by cybersecurity and IoT projects are associated with an increased or decreased likelihood of campaign success. The results show that nine out of ten textual technological topic variables are significantly associated with project success. Topics that are less understood by the audience, such as IoT and Arduino, which is a platform for creating interactive electronic objects that is commonly used for prototyping, are associated with a decreased likelihood of campaign success. These results are in line with previous research that found that the crowd is less familiar with and has less understanding of the meaning and opportunities associated with IoT projects (Molling & Zanela Klein, 2022).

Our findings also show that projects that explicitly mention Smart Home technologies, and cybersecurity projects that provide relatively more information through their title, are more likely to be successful than those that do not. In contrast, software and IoT-related projects are more likely to fail compared to those with other technologies, no matter how success is defined. These findings are in line with previous work by Belleflamme et al. (2014), who found that companies that offer products are more successful in achieving their funding goals than those that offer services.

These results may suggest that backers are not yet familiar with technologies that are typically used in specific innovative communities, such as Arduino, which is commonly used for prototyping in the hardware development communities, or technologies that are relatively new and still not fully understood by the public. Blockchain and cryptocurrency are two such technologies that are often used interchangeably because cryptocurrency typically employs the blockchain technology. Other factors may have also influenced the decision to not back these projects, such as negative publicity and regulatory uncertainty surrounding cryptocurrency in recent years. Overall, these findings imply a lack of confidence by backers in projects involving new technologies.

The significantly positive control variables were found to be in line with Koning and Model (2013), where the number of backers had a strong and positive effect on project success, i.e., a larger number of backers represents a strong signal of project quality and high potential for success. People are more willing to trust a decision made by a large group of other investors in the context of the stock market (Kremer & Nautz, 2013), as well as when making online purchases (Ye & Fang, 2013). The results of this study also indicate that the more unfamiliar the public is with a certain technological term, less money each backer will be willing to invest, and therefore, the more backers are needed for the campaign to be successful. The finding that investors are likely to invest when they understand the project is in line with Härkönen (2014), who emphasized the importance of the public's ability to easily understand the product or service offered by the campaign.

Theoretical and practical implications

Research on entrepreneurial finance emphasizes the challenges related to information asymmetries between investors and start-up companies (Agrawal et al., 2014; Ahlers et al., 2015). These challenges are further exacerbated in crowdfunding, as online platforms arguably offer fewer opportunities for interactions between entrepreneurs and investors (Efrat & Gilboa, 2020). A variety of studies have shown that in order to mitigate the risks associated with information asymmetries, investors put greater emphasis on both the type and the style of information, allowing potential investors to better evaluate projects, which ultimately leads to a higher likelihood of funding success (Dorfleitner et al., 2016; Horvát et al., 2018).

From a theoretical point of view, the results of the various models presented in this study show the importance of textual description in crowdfunding campaigns of projects in specialized industries, such as cybersecurity and IoT, and the importance of sentiment in the campaign's description to the success of a campaign. Although previous research examined the role of sentiment analysis in general crowdfunding campaigns and not in an industry-specific context, this study shows that sentiment is equally important in specialized projects that require investors to have specific knowledge to understand them. This study also demonstrates that previous findings on what drives crowdfunding success in general are also true for very specialized industries, such as cybertechnology and IoT.

From a practical standpoint, the results presented in this study provide further insights for both investors and entrepreneurs interested in investing in specialized projects through crowdfunding platforms. Campaigns need to pay particular attention to the tone of the text used to describe the projects, which should be positive to signal optimism and confidence to potential investors. For example, "Project X" is a cyber violence and governmental surveillance project that eventually failed, possibly partially due to its negative sentiment of − 0.62. Conversely, "Momo," a successful project, was described as a smart home robot equipped with artificial intelligence that was designed as a super hub with standalone security features. The "Momo" project successfully achieved its funding goal, likely in part because of its positive sentiment of 0.9.

Longer project duration negatively and consistently affects the likelihood of success for a campaign. It may therefore be suggested not to use the full duration available on the platform. In our analysis, we found that IndieGoGo

projects had a higher success rate than Kickstarter projects, perhaps due to self-selection bias, where projects with better prospects prefer to raise funds through this platform rather than Kickstarter.

Conclusions

This research investigated the sentiment and description characteristics topics effect on crowdfunding success in specific industries, the IoT and cybersecurity, for the first time. We found that the sentiment of the project description affects the success of crowdfunding campaigns for projects involving cybersecurity and IoT. According to these findings, entrepreneurs are encouraged to pay attention to the text they use to describe their projects, which should be positive, to signal optimism and confidence to potential investors.

In addition, this work demonstrated how the technology textual topics of campaigns that investors are less familiar negatively associated with crowdfunding project success. The findings of this work are expected to provide useful insights for entrepreneurs in the area of cybersecurity and IoT and help them achieve better results and higher success rates in their crowdfunding campaigns.

Limitation and future research

Future works can potentially analyze other platforms and projects in other languages. Considering that this study focused on two of the main crowdfunding platforms that operate in English, testing the hypotheses on platforms that operate in other languages could generalize the findings. Further exploration of the role of sentiments in the crowdfunding industry using, for example, sentiment analysis on comments made by potential backers. Despite the concerns expressed by scholars regarding the suitability of the crowdfunding industry for specialized projects, this work shows that it is possible for such projects to succeed on these platforms. However, we also argue that further investigation of the crowdfunding industry is necessary to unpack the differences between sectors and industries. General findings regarding what drives success in crowdfunding projects are not necessarily relevant for projects in all sectors, and especially when discussing technological projects that require investors to have specialized knowledge to understand them.

Additionally, future research can investigate the seemingly natural behavior of potential crowd investors who do not sufficiently understand a technological project, but are driven by gut feelings about its potential, and are therefore likely to invest less money than they would otherwise, thus resulting in a need for more backers to reach the funding target.

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Data availability Data will be made available upon reasonable request.

Declarations

Conflict of interests The authors declare no competing interests.

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