

## Article

# Mapping Risks Faced by Startup Investors: An Approach Based on the Apriori Algorithm

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**Abstract:** This article maps and verifies the dependence relation between risks faced by startup investors. Thus, a systematic review of 33 articles and a meta-analysis using the Apriori algorithm were used. We mapped 14 investment risks faced by startup investors, classifying them into four dimensions: external, internal, human, and capital. Furthermore, by using the Apriori algorithm, dependency relations between nine investment risks were observed. This research fills a gap related to the non-structuring of a holistic approach to the investment risks startup investors face. In addition, a comprehensive review of and a discussion about the relation between investment risks provides a theoretical foundation for startups' investments based on analyzing the risks inherent to this activity.

**Keywords:** venture capital; investment; investor; startups; risk; apriori algorithm



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## 1. Introduction

The article's objective is to map and verify the dependence relation between the risks faced by startup investors. Startups are new companies which have competitive advantage on products and services innovation (Freeman and Engel 2007; Silva Júnior et al. 2022c), significantly contributing to economic and social development (Audretsch et al. 2006; Song et al. 2008; Reuther et al. 2022). However, despite startups serving as drivers of innovation and competitiveness, they face difficulties surviving the market (Criaco et al. 2014; Kaczam et al. 2022). Most startups fail, a few are relatively successful, and even fewer achieve expressive returns (McConnell 2022). The literature points to a high mortality rate for startups compared to more established companies, reaching the 90% mark (Freeman and Engel 2007; Song et al. 2008; Erdogan and Koohborfardhaghghi 2019), with most startups declaring bankruptcy within five years of operation (Aker and Iqbal 2020). In addition, according to CB insights (2021), the main reason for the startups' failures is the lack of capital and frustrated attempts to raise new funds.

Venture investors are the principal sources of capital for the development and survival of startups. A significant volume of investment in startups was verified worldwide, despite the decrease in total investment compared to 2021 (CB insights 2022; Silva Júnior et al. 2022a). Additionally, considering the number of investment negotiations from 1990 to 2021, Venture Capitalists (VCs) and Business Angels (BAs) were the main types of investments identified. However, in recent years, with other sources of financing growing, the distribution has become more heterogeneous (Silva Júnior et al. 2022a). Regardless of the type of investment, every investor is exposed to high risks when contributing capital to a startup. This is evidenced by the low propensity for financing startups through conventional sources, such as banks, considering the absence of tangible assets and substantial cash flow (Ferrary and Granovetter 2009). Startup investors are exposed to threats, including the dot-com bubble,

in which wildly optimistic investors lost much or all of their equity by funding companies with dubious fundamentals (Howcroft 2001; Ljungqvist and Wilhelm 2003); the 2008 real estate crisis, that caused the bankruptcy of several American financial institutions such as Bank of America, Lehman Brothers, Washington Mutual, and AIG (Monte 2023); and the COVID-19 pandemic, that affected seed capital financing, reducing the number of deals by up to 40% in 2020 compared to pre-pandemic numbers (Brown et al. 2020). Thus, although investment types have been widely studied, the literature lacks comprehensive reviews related to the risks faced by startup investors.

Over the years, literature reviews on the risks faced by startups, critical success factors, and investment decisions have been developed. In Lei et al. (2000), technological, market, and financial risks faced by developing startups were identified. In Wink (2004), the role of risk management in generating knowledge was studied, and its influence on the successful commercialization of recombinant drugs developed by biotechnology startups. In Yu et al. (2012), high-tech startups' operational risks and success factors were identified. In Pereira et al. (2013), a theoretical proposal for a web-based project risk diagnosis tool applied to small- and medium-sized companies and startups was structured. In Bhattacharjee et al. (2021), investors' risk perception was studied in four categories: identifying theories, measurement methods, factors, and the impact of risk perception on investment in equity participation in publicly traded companies. In García et al. (2022), mortality risks in micro- and small companies were studied through a literature review which included 106 articles.

In a study by Ferrati and Muffatto (2019), 208 evaluation criteria were found to be used by investors (BAs and VCs) when making investment decisions in startups. In Santisteban and Mauricio (2017), 21 success factors, grouped into organizational, individual, and external factors, were identified. In Hoegen et al. (2018), six categories of factors which influence the decision-making of crowdfunding investors were identified, as well as how this decision-making differs from other ways of making investment decisions. In Vazirani and Bhattacharjee (2021), based on the last two decades literature, the influencing factors in the investment decisions of VCs were identified, being related to the enterprise, the internal process of the VCs, and the external environment. Finally, 33 articles were reviewed by Alhammad et al. (2022), categorizing the factors influencing reward-based crowdfunding investors into 9 groups: team characteristics, project characteristics, social influence, user-generated content, risk, mistrust, initial marketing, environmental readiness, and supporter motivation.

Therefore, previous research was mainly aimed at identifying critical success factors, investment criteria, and risk perception from a startup internal point of view, as well as the perspective of investors in publicly traded companies. Thus, the present research contributes to the literature by filling the gap related to the comprehensive mapping of risks faced by startup investors, holistically identifying investment risks, and providing insights into the relation between the risks found. The examination of risk characteristics, their categorization, and the exploration of relationships between them using the Apriori algorithm can serve as a valuable reference point for decision-making by investors, managers, and founders in the context of startups.

The remainder of the article is structured as follows: Section 2 presents the methodological procedures for planning and conducting the systematic review (SR) and meta-analysis; Section 3 shows the investment risks identified and the relation between them; Finally, Section 4 presents the final considerations, limitations, and suggestions for future research.

## 2. Methodological Procedures

The methodological procedures are structured in two stages. A review protocol was developed in the first stage to identify the risks. In the second stage, a meta-analysis was performed to establish the relation between the identified risks.

### 2.1. Review Protocol

SRs are used to obtain an overview of the investigated topic, providing insights into existing knowledge and opening avenues for the development of future research (Neuenfeldt Júnior et al. 2022; Francescatto et al. 2022) by using replicable and scientific criteria in the selection of articles incorporated into the textual corpus (Tranfield et al. 2003), which requires the development of a well-defined research protocol (Obregon et al. 2022).

The protocol used was based on the PRISMA 2020 statement, consisting of a checklist grouped into three steps: (a) identification; (b) screening; and (c) inclusion (Page et al. 2021). SRs usually show a lack of awareness of the guidelines used in research development, causing problems related to transparency and replicability. Therefore, PRISMA offers a robust guideline that guarantees the quality of the review and research replicability (Abelha et al. 2020). In the identification stage, the search filters must be defined according to the research questions established ex-ante, which, in this case, were (a) RQ1: What are the risks inherent to the activity of investing in startups?; (b) RQ2: What are the relations between investment risks in the literature?

Thus, the search string was composed by the keywords (“start-up\*” OR “startup\*” OR “entrepreneur\*”) AND (“investment\*” OR “investing\*” OR “investor\*” OR “funding\*” OR “fundrais\*” OR “financing\*” OR “fund\*”) AND (“risk\*” OR “risk management\*” OR “risk evaluat\*” OR “risk assessments\*” OR “risk perception\*” OR “risk analysis\*”); searches were performed in the Scopus and Web of Science databases, as they are the most comprehensive databases for indexing high-impact scientific articles on the subject (Pranckutė 2021). In addition to having a considerable reputation in the scientific community (Alviz-Meza et al. 2023), these two databases provide data for global university rankings (e.g., Times Higher Education global institutional ranking) and bibliometric analyses for global research evaluations (e.g., UNESCO annual scientific report) (Asubiario and Onaolapo 2023). However, these databases may be biased against publications written in non-English, in non-Western countries, and in some areas of knowledge such as arts, humanities, and social sciences (Tennant 2020).

Based on the search filters shown in Table 1, 3351 articles were found, and, after eliminating duplicates and completing the identification step, 2591 articles remained.

**Table 1.** Search filters.

Filter	Scopus	Web of Science
Type	Articles and conference papers	Articles and conference papers
Search in	Title, abstract, or keywords	Topic
Subject areas	Engineering; Decision Sciences; Business, Management, and Accounting; Economics, Econometrics, and Finance	Economics; Management; Business; Business Finance; Operations Research Management Science; Engineering Industrial; Engineering Manufacturing; Engineering Multidisciplinary
Years	No filter	No filter

In the screening stage, the titles and abstracts of the articles were analyzed considering, as an inclusion criterion, only articles that potentially presented investment risks in startups, reducing the textual corpus to 353 articles. Then, to refine the search, the following screening criteria were applied: (a) only journals in the Q1, Q2, and Q3 quartiles of the Scimago Journal & Country Rank (SJR), or (b) only articles with a minimum average citation of 1 as of October 2022. Based on these criteria, it was possible to select articles published in higher quality journals and that had a relative scientific impact considering the citations received. Thus, 253 articles remained for full reading, wherein 220 articles were excluded for not presenting any aspect of investment risk in startups.

For the inclusion stage, data extraction from and a qualitative and quantitative synthesis of the remaining 33 articles were developed, as the articles presented at least one type of investment risk in startups. Books, chapters, short articles, expanded summaries, and non-English articles were also disregarded. Data extraction was performed using an Excel spreadsheet. Information was extracted from the article's title, authors, journal, year of publication, research objective, sample characteristics, research method, identified risks, main results, limitations, and future research considerations. Figure 1 shows the flow of the PRISMA 2020 statement at each stage mentioned.

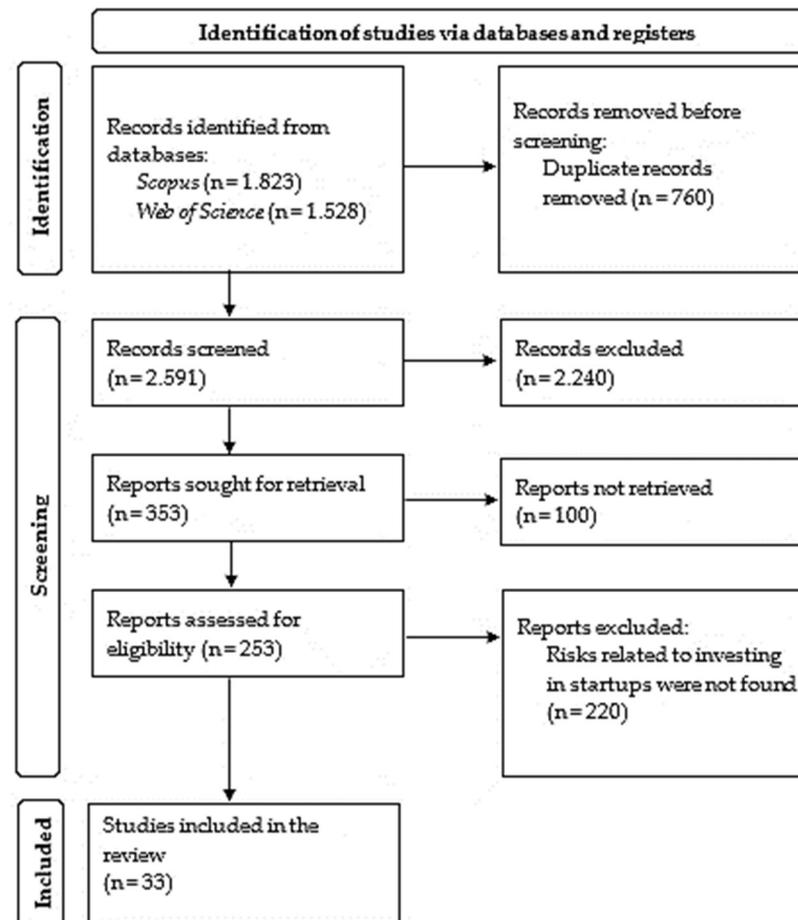


Figure 1. PRISMA 2020 flow diagram statement used to include articles in the SR.

An overview of the articles belonging to the SR textual corpus, which provides additional information about the journal, methodology, sample, and application country of the studies, is presented in Appendix A.

## 2.2. Meta-Analysis

Meta-analysis relates to using statistical techniques to synthesize articles included in an SR (Moher et al. 2009). Association rules using the Apriori algorithm allow the principal relations between identified investment risks to be shown, building association rules according to the correlation between frequent risk sets (Wang et al. 2022). The Apriori algorithm extracts patterns and identifies the main Boolean association rules among the most frequent risk sets (Agrawal and Srikant 1994). In addition, the Apriori algorithm identifies relations considering the dependence and confidence level between the risks (Da Costa et al. 2019; de Carvalho et al. 2022).

WEKA software was used to execute the Apriori algorithm, where:  $R = \{r_1, r_2, \dots, r_m\}$  represents the set of risks,  $W$  represents the set of transactions, and  $F = \{f_1, f_2, \dots, f_m\}$ ,

$(f_i \subset R)$  represents a transaction in  $W$  (Turčinek and Turčínková 2015; Cheng et al. 2016; Wang et al. 2022). The sets composed of the risks were represented by  $A$  and  $B$ , respectively, and the implication in the form  $A \rightarrow B$  represented the association rules  $W \in A \cap B = \emptyset$ .

WEKA compares the minimum support ( $S$ ) predefined by the user and the minimum confidence ( $C$ ) considering the set of transactions  $W$ , to find the qualified association rules (Wang et al. 2022). Support indicates the frequency at which  $A$  and  $B$  appear together in  $W$ , as shown in Equation (1). Confidence indicates the association rules' strength and the transaction number of  $A$  and  $B$  simultaneously contained in  $W$ , as shown in Equation (2). Finally, the lift ( $L$ ) indicates the correlation between the occurrence of risks, as shown in Equation (3).

$$S(A \rightarrow B) = P(A \cup B) \tag{1}$$

$$C(A \rightarrow B) = P(A \cup B) / P(A) \tag{2}$$

$$L(A, B) = [P(A \cup B) / (P(A) \times P(B))] \tag{3}$$

For  $L < 1$ , occurrences of  $A$  and  $B$  are negatively correlated. If  $L > 1$ , the occurrences of  $A$  and  $B$  have a positive correlation, and, for  $L = 1$ ,  $A$  and  $B$  are independent (Da Costa et al. 2019). To ensure the best risk association rules, the metrics for structuring the relation network between investment risks are (a) confidence greater than or equal to 0.5 and (b) lift greater than or equal to 1.

### 3. Results and Discussions

The results are presented in three subsections: the first subsection presents information about the overview of the textual corpus, the second subsection shows the risks identified in the selected articles, and, finally, the third subsection demonstrates the relation between the risks based on the Apriori algorithm association rules.

#### 3.1. Overview of the Textual Corpus

A total of 23 articles (69.7%) were published from 2000 onwards as a consequence of the internet bubble burst, which caused an increase in investor concerns about the risks involved in financing startups (Ljungqvist and Wilhelm 2003; Min et al. 2008; Bouwman et al. 2012; Silva Júnior et al. 2022b).

In addition, the textual corpus was classified by investor type, with  $n$  being each investor type's number of occurrences. VCs were the most investigated investors ( $n = 18$ ), followed by BAs ( $n = 12$ ), crowdfunding ( $n = 4$ ), banks ( $n = 2$ ), corporate venture capital (CVC) ( $n = 1$ ), and IP capital ( $n = 1$ ). Figure 2 shows the distribution of investor types from 1985 to 2022. The numbers inside the graph represent the identified investors per period.

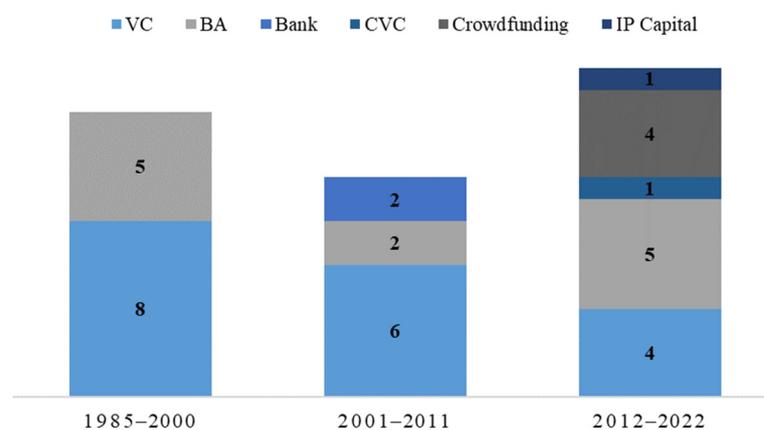


Figure 2. Distribution of articles by type of investor.

Six investor types were verified, i.e., not restricted only to BAs and VCs, but also expanding to other investors from 2001–2011, including banks and, more explicitly, in 2012–2022, CVC, crowdfunding, and IP capital.

VCs are institutional investors who prefer to operate in high-risk and uncertain environments (Bygrave 1988; Bellavitis et al. 2017; Polzin et al. 2018), seeking high-risk startups with a high potential return on investment (Baum and Silverman 2004). Despite traditionally operating in early-stage companies, VCs invest in advanced-stage companies (Bellavitis et al. 2017; Dai et al. 2022), intending to diversify the portfolio in more experienced companies and reduce exposure to risk (Witt and Brachtendorf 2006).

The change in the investment dynamics of VCs opened an opportunity for angel investors, one of the most significant funding sources for early-stage startups (Sohl 2022). BAs are individual investors who, in addition to contributing with capital, also closely monitor the evolution of invested startups (Haar et al. 1988; Van Osnabrugge 2000; Mason et al. 2022). As noted by Landström and Sørheim (2019), research on BAs has evolved from a first generation of studies aimed at characterizing BAs and their market size, through understanding the decision-making process and political issues related to BAs (second generation), to a third generation of researchers who study trust and conflicts between BAs and entrepreneurs, types of BAs, and angel investment trends over time. In addition to the three generations of studies presented in Landström and Sørheim (2019), in Harrison and Mason (2017), a fourth generation of studies more focused on the dynamics of market evolution was shown.

Furthermore, technological development has provided new ways of making investments. Crowdfunding is a modality that brings together investors looking for innovative businesses and companies looking for funding through online platforms (e.g., Crowdfunder and Kickstarter), providing an option to fill the capital gap for early-stage startups (Angerer et al. 2018; Kleinert and Volkmann 2019) and to attract experienced investors, mainly due to the platforms' ease of use (Wasiuzzaman et al. 2022).

Banks have more significant restrictions on financing startups due to the high credit risk involved. Therefore, banks tend to finance startups in exchange for equity, looking mainly for startups which have already developed a product or service (Mason and Harrison 2004; Schäfer et al. 2004; Huyghebaert and Van De Gucht 2007). In addition to banks, large companies also invest in startups through subsidiary companies (CVC), functioning as parent company fund managers (Widyasthana et al. 2017). Another type of investment observed in the textual corpus is venture funds based on intellectual property, aimed to finance patented or patentable inventions even before establishing an early-stage startup, ensuring return on investment through royalties and the sale of patents or equity participation (Jarchow and Röhm 2020).

### 3.2. Investment Risks in Startups

A total of 14 risks were identified in the textual corpus, grouped into four dimensions based on similarities, namely, (a) external, (b) internal, (c) human, and (d) capital. In Table 2, the list of risks are coded and grouped into the dimensions, along with the number of citations for each risk and the percentage of citations, considering the 33 articles in the textual corpus.

In the following sections, the identified investment risks are defined and explained according to the four-dimension grouping.

**Table 2.** Identified investment risks.

Dimension	Code	Risks	Citations	Percentage
External	R1	Market	17	51.5%
	R2	Location	1	3.0%
	R3	Political–Regulatory	2	6.1%
	R4	Intermediary	1	3.0%
Internal	R5	Valuation	5	15.2%
	R6	Product	16	48.5%
	R7	Business model	2	6.1%
	R8	Performance	5	15.2%
Human	R9	Management	6	18.2%
	R10	Credibility	3	9.1%
	R11	Agency	18	54.5%
	R12	Know-how	3	9.1%
Capital	R13	Financial	8	24.2%
	R14	Liquidity	4	12.1%

### 3.2.1. External Dimension

The external dimension is composed of risks investors cannot reduce or eliminate (Witt and Brachtendorf 2006; Harrison and Mason 2017; Kleinert and Volkmann 2019). Four types of investment risks are found within the external dimension: market, political–regulatory, location, and intermediary.

Market is the most prominent risk in the external dimension, mentioned in 17 of the 33 selected articles, being related to the startup’s success uncertainty in the market (Mamonov and Malaga 2019) and to the unforeseen competitive conditions which can affect the size, growth, and level of market demand (Fiet 1995a; Frias et al. 2020). Furthermore, market risk is the possibility that the product/service has insufficient demand due to competition or entry barriers (Polzin et al. 2018).

As reported by Carpentier and Suret (2015), one of the main reasons preventing startups from receiving funding is related to market risk, originating from the difficulty for investors in assessing the market potential for products/services that may not exist or need to create a new market (Mason and Harrison 2004; Polzin et al. 2018). However, research suggests investors have a more significant risk appetite when market risk is more remarkable, indicating investor overconfidence or an optimistic bias toward the market (Parhankangas and Hellström 2007; Polzin et al. 2018). In addition, there is the possibility the startup does not prove to be scalable enough to reach pre-established goals, being required to demonstrate exponential growth in a short period. Thus, management, financial, and technical challenges tend to be greater when compared to traditional and more established companies (Mamonov and Malaga 2019; Frias et al. 2020). Moreover, the entry time into a highly competitive market can be decisive for an innovative company success or failure; therefore, startups are often characterized by short “windows of opportunity” and may not be successful if they enter too late or too early into the market (Mason and Harrison 2004).

The political–regulatory risk is related to the possibility of changes in government regulation impacting the startup’s business model, which raises investors’ concerns due to the impossibility of management (Polzin et al. 2018). However, an investor’s perception of legal risk is directly proportional to the amount of capital invested in startups on crowdfunding platforms, as more legislation imposes high disclosure costs for startups (Wasiuzzaman et al. 2022).

Location risk has little prominence within the external dimension (along with intermediate risk) and results from the geographic distance between the investor and the investee startup. Investors tend to invest in local startups which are geographically close to the investor, but also target global markets having synergy with their investment portfolio (Widyasthana et al. 2017).

Finally, the intermediary risk relates to the possibility of a preliminary startup quality assessment by an intermediary, such as an Equity Crowdfunding platform. Crowdfunding investors tend to reduce investment risks by avoiding investments in less attractive projects, which leads to more concentrated funding. Therefore, startups considered unattractive on crowdfunding platforms have more difficulty raising funds (Angerer et al. 2018).

### 3.2.2. Internal Dimension

Investors can actively manage risks coupled with the internal dimension. This dimension had the second highest prominence (84.8%) and is divided into four types of investment risks: product, valuation, performance, and business model.

Product risk was cited in 14 articles in the textual corpus; it relates to the possibility of an investor contributing capital to a project of uncertain quality (Cumming et al. 2005). Thus, the product may not be accepted by the market, may not be competitive enough (Haar et al. 1988; Rea 1989; Norton and Tenenbaum 1993), or may result in costs higher than what was planned (Polzin et al. 2018). Furthermore, the technology may not be appropriately tested and proven, and the development may take longer than expected; therefore, the product may be outperformed by competitors (Mason and Harrison 2004).

Product risk is higher in startups because of the products' novelty degree and services developed (Angerer et al. 2018). However, even though product risk is more pronounced in startups, investors with a solid background within the technology industry can add value to the startup by mitigating product risk (Mason and Harrison 2004).

Failures in implementing the product/service can increase the investor's exposure to product risk (Mamonov and Malaga 2019). Investors look for companies with a clear vision of developing products/services, which have already developed a functional prototype, and which have some market acceptance, as they are more protected from product risk (Polzin et al. 2018; Macmillan et al. 1985). Product risk can be assessed considering the venture novelty degree and the company's ambition. Regarding the startup newness degree, the risk is greater if the investment is spent on developing a new product (completely new, without considering improvements in existing products or improved models of other products). Considering the project ambition, the greater the investment to develop a new market or technology, the greater the product risk (Schäfer et al. 2004).

As for valuation risk, startups generally lack a full range of tangible assets and a track record of consolidated performance. Thus, startup valuation is complex because it depends heavily on the intangible assets' potential value. Therefore, traditional valuation methods are not fully applicable in this context (Carpentier and Suret 2015), with the possibility of the investor obtaining an equity share at a valuation above the fair market value (Carpentier and Suret 2015; Wasiuzzaman et al. 2022).

Performance risk relates to the possibility of the startup not developing as planned, frustrating investor expectations (Söderblom et al. 2016). According to Widyasthana et al. (2017), the startup's involvement with the other ecosystem stakeholders can reduce the investment risk, increasing the performance and, subsequently, the startup's success. In addition, performance objectives can be used as a performance risk mitigation tool (Kaplan and Strömberg 2004).

Finally, business model risk represents the possibility that a startup's business model is not sustainable in the long term. The business model must be viable and show potential for profitability. Actions related to strategy and business model development are less likely to generate conflicts between investors and founders. Therefore, investors tend to play an active role in designing employee compensation, developing business plans, implementing information systems, accounting, and assisting in acquisitions (Kaplan and Strömberg 2004).

### 3.2.3. Human Dimension

The human dimension covers 90.9% of the selected articles, being linked to human factors related to uncertainties regarding the investments' success, differentiated by four risk categories: agency, management, credibility, and know-how.

Agency risk was mentioned in 18 of the 33 articles in the textual corpus; it is caused by divergences in interests between investors (principals) and entrepreneurs (agents) resulting from bad faith, conflicting objectives, or lack of capacity (Reid 1996; Bellavitis et al. 2017; Cowden et al. 2020; Dugar and Basant 2021). Differences between investors and entrepreneurs derive from information asymmetry, resulting in moral hazard and adverse selection (Parhankangas and Hellström 2007; Jarchow and Röhm 2020). An asymmetry of information is verified when one side of the negotiation dominates more information, which can cause a moral hazard related to higher than normal risk-taking by the agent (Cowden et al. 2020).

Conversely, adverse selection is the possibility of the investor choosing a bad alternative based on the asymmetric information obtained; thus, the investor cannot accurately observe the skills and capabilities of entrepreneurs during negotiation (Van Osnabrugge 2000; Cumming 2006). In addition, the investor finds it difficult to conduct due diligence due to the high costs generated by the novelty and complexity of the technology, the product, and the market (Mason and Harrison 2004).

Another risk for investors when financing a startup is management, related to the inability of managers or founders to manage the startup. The results of Kaplan and Strömberg (2004) suggest that the prominence of risk management is related to information asymmetry and moral hazard. Depending on the startup's development stage, the management risk is more pronounced. In the early stages of the life cycle, management failures are identified as more frequent compared to later stages (Ruhnka and Young 1987; Widyasthana et al. 2017), which can be explained by the founders' high technical knowledge, but insufficient knowledge related to management and sales (Mason and Harrison 2004). However, managers' lack of experience is not the main reason for not receiving investment, although more experienced entrepreneurs are more likely to receive funding (Carpentier and Suret 2015). For Haar et al. (1988), the ability of the management team to calculate and react well to risks, in addition to being attentive to details and market changes, positively affect a company's success.

Credibility risk is related to the reputation and ability of the startup team and founders to achieve established goals. According to the results of Rea (1989) and Angerer et al. (2018), the lack of credibility is considered one of the most critical risks for failure in investment negotiations. In addition, investors' perception of risk is related to employees' ability and efficiency in performing key activities (Widyasthana et al. 2017). Furthermore, the lack of reputation of project initiators on crowdfunding platforms increases investors' perception of risk (Angerer et al. 2018).

Know-how risk was the least cited in the textual corpus, observed in two aspects. The first aspect relates to the fit between the startup proposal and the thesis adopted by the investor (Kaplan and Strömberg 2004; Widyasthana et al. 2017). The second aspect is related to the risk of the investor's ignorance about the sector of activity, technology, or product/service developed by the investee (Haar et al. 1988; Widyasthana et al. 2017). Thus, the value the investor adds to the startup is most harmed when the risk of know-how is most pronounced.

#### 3.2.4. Capital Dimension

The capital dimension is the least prominent within the textual corpus, covering 36.4% of citations, and is related to the direct financial consequences of investing in startups. All investment risk can be related to financial aspects; however, the capital dimension was categorized separately to emphasize a strictly monetary aspect in the analysis of investment risks, encompassing financial and liquidity risks.

Financial risk is related to the investor losing all invested capital (Norton and Tenenbaum 1993; Wasiuzzaman et al. 2022). Thus, startups managed by skilled entrepreneurs, with a history of success, in high-growth markets, and with the prospect of a considerable return on investment can minimize the risk of a total loss of investment (Macmillan et al. 1985; Polzin et al. 2018; Wasiuzzaman et al. 2022). Financial risk negatively affects the investment

decision, increasing investor risk aversion resulting from the asymmetry of information involved in the investment process (Wasiuzzaman et al. 2022). Even if all capital is not lost, there is still a risk that the return on investment (ROI) will be lower than expected by the investor (Rea 1989; Polzin et al. 2018).

Another risk is liquidity; if it is impossible for the investor to obtain the invested capital back, they needing to maintain the investment in the startup or redeem it with loss (Cumming et al. 2005). Startup investors can hardly sell their stakes to third parties, making liquidity very low. In this regard, there are two aspects of liquidity risk. The first aspect relates to the difficulty in exiting a business likely to go bankrupt, comprising internal and external factors to the management team. In contrast, the second aspect is related to the exit from a successful investment, where investors prefer to leave when the market assigns a fair price to the business (Norton and Tenenbaum 1993).

### 3.3. Relationship Network between Investment Risks

The relationship network between the identified investment risks using the Apriori algorithm association rules presented in Table 3 is discussed. Only the association rules with confidence equal to or greater than 0.50 and lift equal to or greater than 1.0 were considered, being applied to both antecedent and successor. For example, the association between risks R6—Product Risk and R1—Market Risk is used. Risk R6 is the antecedent (A) and R1 is the successor (B).

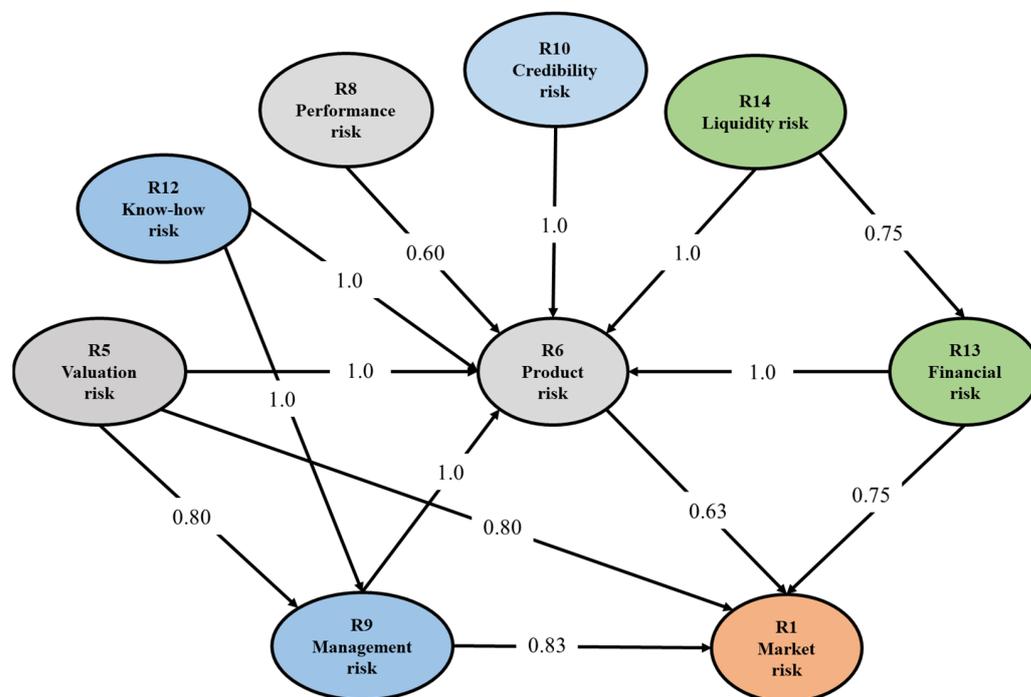
**Table 3.** Investment risk association rules, obtained by applying the Apriori algorithm.

Associations			Rules		
Antecedent	Occurrences as the Antecedent	Successor	Occurrences as the Successor	Confidence	Lift
R13—Financial risk	8	R6—Product risk	8	1.00	2.06
R9—Management risk	6	R6—Product risk	6	1.00	2.06
R5—Valuation risk	5	R6—Product risk	5	1.00	2.06
R14—Liquidity risk	4	R6—Product risk	4	1.00	2.06
R12—Know-How risk	3	R9—Management risk	3	1.00	5.50
R12—Know-How risk	3	R6—Product risk	3	1.00	2.06
R10—Credibility risk	3	R6—Product risk	3	1.00	2.06
R9—Management risk	6	R1—Market risk	5	0.83	1.62
R5—Valuation risk	5	R9—Management risk	4	0.80	4.40
R5—Valuation risk	5	R1—Market risk	4	0.80	1.55
R13—Financial risk	8	R1—Market risk	6	0.75	1.46
R14—Liquidity risk	4	R13—Financial risk	3	0.75	3.09
R6—Product risk	16	R1—Market risk	10	0.63	1.21
R8—Performance risk	5	R6—Product risk	3	0.60	1.24

Support represents the ratio between the number of joint risk citations and the total number of articles. In this case, R6 and R1 are cited together at least 10 times, according to Table 3 in the column “Occurrences as successor”; therefore, considering the total number of articles in the textual corpus ( $n = 33$ ),  $S(A \rightarrow B) = P(A \cup B) = 30.3\%$ . Confidence corresponds to the number of transactions that contain A (16 times according to Table 3, column “Occurrences as antecedent”) and contain B (10 times according to Table 3, column “Occurrences as successor”). Thus,  $C(A \rightarrow B) = P(A \cup B) / P(A) = 63\%$ . Finally, the Lift is calculated as the relation between  $S(A \rightarrow B) = 30.3\%$  and the multiplication of the probabilities of A (16 times according to Table 3) and B (17 times according to Table 2) occurrences throughout the data set. Therefore,  $P(A) = 16/33 = 0.4848$ ,  $P(B) = 17/33 = 0.5151$ , and  $L(A, B) = [P(A \cup B) / P(A)P(B)] = 1.21$ .

Figure 3 presents the relationship network between investment risks, built according to the best association rules. Of the 14 investment risks identified, 9 are in the relationship network. The numbers on the arrows represent the confidence between two risks. For example, considering the relationship between R6—Product Risk and R1—Market Risk,

in 63% of the articles, R6 and R1 are cited together. In addition, the colors represent each risk dimension. The gray color represents the internal dimension, the blue is the human dimension, the green is the capital dimension, and the orange is the external dimension.



**Figure 3.** Investment risk relationship network.

The R6—Product Risk is connected to eight other investment risks, being cited in 48.5% of the articles. Furthermore, the risks connected to product risk are part of the four defined dimensions. In addition, another significant risk in the network is R1—Market Risk, which is connected to four other investment risks and is mentioned in 51.5% of the articles. Investment risks connected to market risk are present in human, internal, and capital dimensions.

Considering the internal dimension, valuation and performance risks are connected with product risk, with a confidence of 1.0 and 0.60, respectively. Furthermore, valuation risk shows a dependency relationship with market and management risks, with a confidence of 0.80. Moreover, product risk is intertwined with market risk, with a confidence of 0.63.

Startups with an overestimated market value linked to products not protected by patents and a target market with growth restrictions are characteristics which disqualify proposals for funding, posing risks to investors (Haar et al. 1988). Therefore, the proposed technology novelty can influence the asymmetry between product/service maturity, the existence or absence of a consumer market, and startup valuation (Mason and Harrison 2004). Thus, the startup valuation must match the product/service development stage and the potential market in which the solution should be inserted. However, results in Wasiuzzaman et al. (2022) show the relation between the difficulty in calculating the startup valuation and the positive influence on the crowdfunding investors' risk aversion, as opposed to the degree of marketed product novelty, without significant influence. In this case, the investors' youth (mostly aged between 21 and 40) in the research sample possibly influenced the result (Wasiuzzaman et al. 2022).

The dependency relationship between performance risk and product risk relates to the maturity level of the product/service and the influence on startup performance. In Kaplan and Strömberg (2004), the startup positive performance can be measured by considering the degree of development and product positioning in the market to reach the

expected revenue goal. In this sense, knowledge of the product nature serves as a basis for minimizing investment risks in startups (Widyasthana et al. 2017).

Product and market risks are primarily responsible for the rejection of investment requests submitted by startups (Carpentier and Suret 2015). BAs are more interested in products already accepted in the market than in features such as intellectual property protection and patents (Polzin et al. 2018; Haar et al. 1988). Investors specialized in a given industry can minimize investment risks, adding value to invested startups (Norton and Tenenbaum 1993; Mason and Harrison 2004; Mamonov and Malaga 2019). Still, there is a mismatch in the perception of investment risks between entrepreneurs and investors (Frias et al. 2020). However, despite similarly perceiving product risk, investors are more concerned with the market and political environment than entrepreneurs (Polzin et al. 2018).

Concerning the human dimension, three investment risks are related to the product risk, presenting a confidence of 1.0: management, credibility, and know-how. Furthermore, management risk is linked to market risk, with a confidence of 0.83. In Haar et al. (1988), it was verified that BAs' main concerns are related to the entrepreneur's competence in managing a startup linked to developing a product which does not satisfy the market's needs. In addition, one assumption by Kaplan and Strömberg (2004) was that, as a quality driver, management represents the ability of the founder or CEO to develop a product of excellence while consuming a modest amount of capital.

Furthermore, the management team founder's previous experience has no significant effect on rejecting funding proposals for product-related reasons. Thus, investors relate management risk to other categories instead of just considering the manager's previous experience as a driver of management quality. Furthermore, the lack of maturity and limited knowledge about competitors and the management team's positioning in the competitive market led to the rejection of investment proposals (Carpentier and Suret 2015).

The dependence between credibility risk and product risk can be understood in two ways: the team's credibility and the founder's or CEO's credibility. The team's lack of credibility is related to gaps in teamwork, training, and knowledge, affecting the quality of the product/service developed and, consequently, increasing the risk to investors. Additionally, Rea (1989) demonstrated that even, if the company has a superior product or service, the team's lack of credibility is one of the main failure risks in investment negotiations.

From the founder's or CEO's credibility point of view, credibility risk can be measured based on the founder's previous experience and education level (Widyasthana et al. 2017). In addition, crowdfunding investors are inherently exposed to credibility risk, considering the relative absence of information proving the founder's reputation and startup product/service quality on crowdfunding platforms (Angerer et al. 2018).

Know-how risk concerns the investor's experience or prior knowledge of the invested startup, which may represent the investment risk perception to a greater or lesser extent. The dependency relationship between product risk and know-how risk relates to the lack of familiarity between the investor and the investee company's operating sector or the product offered (Haar et al. 1988).

Regarding the capital dimension, liquidity risk and financial risk are in a dependency relationship with the product risk, with a confidence of 1.0. In addition, liquidity risk is dependent on financial risk, with a confidence of 0.75. Furthermore, financial risk is related to market risk, with a confidence of 0.75.

Evidence suggests that VCs' willingness to invest in startups with a high product risk is directly proportional to liquidity risk conditions (Cumming et al. 2005). Thus, the higher the liquidity risk, the more likely VCs are to invest in early-stage startups. This result is related to the long-term mindset of investors, who prefer to expose themselves to greater liquidity and product risks in search of a greater return on investment. In addition, liquidity risk can be minimized through a diversified portfolio of startups, not only by industry, but

also across different funding stages (Norton and Tenenbaum 1993; Cumming et al. 2005; Wasiuzzaman et al. 2022).

Regarding the possibility of total investment loss, Polzin et al. (2018) suggest that entrepreneurs underestimate the importance of financial risk for investors, which may mean entrepreneurs prioritize obtaining financing to bring innovative technology to the market. Investors, in turn, need a clear explanation of how the capital will be used in the developed innovation technical and commercial viability. Likewise, according to Rea (1989), VCs are more interested in the business's financial aspects than the product's technical aspects. In contrast, Norton and Tenenbaum (1993) suggest business-specific risk management (e.g., technology and marketing) is more critical for VCs than financial risk.

In addition to the product, financial risk is directly linked to market risk, given that startups develop a product that has the potential to not be absorbed by the target audience due to the high competitiveness or market limitations, resulting in total investment loss (Kaplan and Strömberg 2004). Moreover, a market with high growth potential presents an essential aspect for startup investment decisions (Rea 1989).

A surprising result of the Apriori algorithm is the absence of agency risk in the relationship network, explained by the Lift found between market risk and agency risk (Lift = 0.75). Market risk and agency risk have a negative correlation of occurrence, being outside the criteria established in Section 2.2, suggesting most of the literature deals with agency risk separately from other investment risks (Reid 1996; Van Osnabrugge 2000; Cumming 2006; Huyghebaert and Van De Gucht 2007; Knyphausen-Aufse and Westphal 2008; Bellavitis et al. 2017; Cowden et al. 2020; Dugar and Basant 2021), or even together with a few other risks, such as market (Fiet 1995a, 1995b; Witt and Brachtendorf 2006; Mamonov and Malaga 2019), business (Sapienza et al. 1996), and product (Mamonov and Malaga 2019; Jarchow and Röhm 2020), justifying the absence in the relations network formed through the Apriori algorithm.

Agency risk may be more pronounced, considering the type of investment made in the startup. Thus, BAs and crowdfunding investors perceive agency risk more than VCs. Surveys involving BAs and crowdfunding investors tend to emphasize agency risk, which occurs to a lesser extent in surveys involving VCs (Fiet 1995b, 1995a; Harrison and Mason 2017). This may explain the absence of agency risk in the network of risk relationships. In this sense, the present study that encompasses the risks of investing in startups becomes even more important in order to establish a comprehensive view of the subject.

#### 4. Conclusions

This research mapped and verified the dependency relations between risks faced by startup investors. From an in-depth review of 33 articles, 14 investment risks in startups were identified and grouped into four dimensions: external, internal, human, and capital. Risks were inserted into each dimension according to shared characteristics. In addition, the relations between investment risks were established using the Apriori algorithm, thereby determining the dependency relation between them.

With the SR, it is observed that previous research did not cover the various risks that startup investors are exposed to, nor did it establish dependency relations between them. The most frequent risks within the textual corpus were agency, market, and product risks. Furthermore, market and product risks showed the highest number of dependency relations with other risks, demonstrating their relevance for decision-making and risk management of investments in startups. In addition, behavior involving agency risk was verified. Despite being widely studied, agency risk still has an isolated character, demonstrating a need to be studied in conjunction with other risks.

In addition, this article provided a theoretical foundation related to investment in startups based on the analysis of the risks inherent to this activity. Thus, we have contributed to the literature by expanding the discussion about investment risks and using an innovative approach within entrepreneurship, investment, and risk management research. Still, the

risks with the highest occurrence in the literature can serve as a parameter for investment assessments by investors and for decision-making by managers of startup founders.

As a limitation, the direct relation between only two investment risks simultaneously through the association rules of the Apriori algorithm was developed, not considering the relations between three or more risks. Future research may establish more complex networks of risk relations. Additionally, research can be developed considering investors located in emerging economies since, despite research carried out in Malaysia (Wasiuzzaman et al. 2022), India (Dugar and Basant 2021) and Indonesia (Widyasthana et al. 2017), most articles in the textual corpus are in developed countries (see Appendix A). Finally, new research can establish indicators for measuring the identified investment risks, providing investors with a quantitative and qualitative approach, as well as an assessment of the risks they will be exposed to when financing startups.

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## Appendix A

This appendix shows the studies within the textual corpus.

**Table A1.** Overview of the selected articles.

References	Journal	Method	Sample	Country
Angerer et al. (2018)	Journal of Small Business Strategy	Quantitative	210 crowdfunding investors	Germany, Switzerland, Austria, and Liechtenstein
Bellavitis et al. (2017)	Journal of General Management	Quantitative	265 investments made in 127 companies by 90 VCs	Belgium, France, Germany, Sweden, Netherlands, UK, and US
Carpentier and Suret (2015)	Journal of Business Venturing	Quantitative	636 projects submitted to a group of BAs	Canada
Cowden et al. (2020)	Journal of Small Business Strategy	Theoretical	None	N/A
Cumming (2006)	Entrepreneurship: Theory and Practice	Quantitative	4114 first rounds of investment in startups and growth companies	Canada
Cumming et al. (2005)	Financial Management	Quantitative	18,774 investment rounds taken from the VentureXpert dataset of Venture Economics	US
Dugar and Basant (2021)	Journal of Emerging Market Finance	Quantitative	5782 deals in startups by VCPE (Venture Capital-Private Equity) firms.	India

Table A1. Cont.

References	Journal	Method	Sample	Country
<a href="#">Fiet (1995a)</a>	Journal of Business Venturing	Quantitative	245 VCs e 849 BAs	US
<a href="#">Fiet (1995b)</a>	Journal of Management Studies	Quantitative	245 VCs e 849 BAs	US
<a href="#">Frias et al. (2020)</a>	Journal of Macromarketing	Quantitative	Sample 1: 41 exploratory interviews; Sample 2: 36 angel investors and 70 startup entrepreneurs	US
<a href="#">Haar et al. (1988)</a>	Journal of Business Venturing	Quantitative	121 BAs	US
<a href="#">Harrison and Mason (2017)</a>	International Review of Entrepreneurship	Quantitative	127 BAs	UK
<a href="#">Huyghebaert and Van De Gucht (2007)</a>	European Financial Management	Quantitative	244 manufacturing startups	Belgium
<a href="#">Jarchow and Röhm (2020)</a>	Journal of Small Business Management	Qualitative	6 intellectual property-based investment funds	UK and US
<a href="#">Kaplan and Strömberg (2004)</a>	Journal of Finance	Quantitative	67 investments made by 11 VC firms	US
<a href="#">Kleinert and Volkmann (2019)</a>	Venture Capital	Quantitative	574 discussions in 2258 days of Crowdcube observation	UK
<a href="#">Knyphausen-Aufse and Westphal (2008)</a>	Venture Capital	Multiple case studies	42 investments from a BAs network	Germany
<a href="#">Macmillan et al. (1985)</a>	Journal of Business Venturing	Quantitative	102 VCs	US
<a href="#">Mamonov and Malaga (2019)</a>	Venture Capital	Quantitative	337 startups posted on the Crowdfunder platform	US
<a href="#">Mason and Harrison (2004)</a>	Venture Capital	Quantitative	127 BAs	UK
<a href="#">Norton and Tenenbaum (1993)</a>	Journal of Business Venturing	Quantitative	98 VCs	US
<a href="#">Parhankangas and Hellström (2007)</a>	Venture Capital	Quantitative	90 Investment Managers in 58 VC Firms	Sweden and Finland
<a href="#">Polzin et al. (2018)</a>	Technological Forecasting and Social Change	Quantitative	Sample 1: 4 entrepreneurs and 12 investors (VCs and BAs); Sample 2: 6 entrepreneurs and 13 investors (VCs and BAs)	Sweden and Netherlands
<a href="#">Rea (1989)</a>	Journal of Business Venturing	Quantitative	89 VCs	US
<a href="#">Reid (1996)</a>	Small Business Economics	Case study	1 VC and 1 startup	UK
<a href="#">Ruhnka and Young (1987)</a>	Journal of Business Venturing	Quantitative	73 VC firms	US
<a href="#">Sapienza et al. (1996)</a>	Journal of Business Venturing	Quantitative	Sample 1: 65 VCs; Sample 2: 76 VCs; Sample 3: 43 VCs; Sample 4: 37 VCs	US, UK, France, and Netherlands
<a href="#">Schäfer et al. (2004)</a>	Industry and Innovation	Quantitative	228 investment observations from KfW bank (45% loan and 55% equity)	Germany
<a href="#">Söderblom et al. (2016)</a>	Venture Capital	Multiple case studies	4 BAs and 4 startup founders	Sweden

Table A1. Cont.

References	Journal	Method	Sample	Country
Van Osnabrugge (2000)	Venture Capital	Quantitative	119 VCs e 143 BAs	UK
Wasiuzzaman et al. (2022)	Journal of Entrepreneurship in Emerging Economies	Quantitative	169 Equity Crowdfunding investor responses	Malaysia
Widyasthana et al. (2017)	Journal of Entrepreneurship Education	Quantitative	3 startups and 5 support agents (CVC, VCs, government, customer and agent portfolio company)	Indonesia
Witt and Brachtendorf (2006)	Financial Markets and Portfolio Management	Quantitative	89 VC-funded startups	Germany

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