Toward a Technical Debt Relationship with the Pivoting of Growth Phase Startups

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Abstract. Context: Pivot has been a common strategical tactic of startups by shifting course of actions to adapt to environmental changes to the companies. Among many factors influencing the decisions of pivot or preserve, technical characteristics of the product and its evolution are possible triggering factors. We have learned that technical debt is an inherent phenomenon in startups that hinders later growth. However, we do not yet know how technical debt might lead to pivoting in startups and what TD processes we observe in different pivoting scenarios. Aim: Our goal is to evaluate how technical debt influences pivoting in growth-phase startups. Methodology: We conducted an empirical study on 11 software startups in Norway and Brazil and analyzed qualitative data using thematic analysis. Results: We identified three ways that technical debt influences pivoting: (1) direct, (2) indirect, and (3) no-influence. Managing and avoiding technical debt significantly reduces the likelihood of technology pivoting and restrains indirect effects on other pivoting types. Contribution: Our study will enable practitioners to address the influence of technical debt on pivoting in growth-phase software startups. Future researchers can benefit from our findings by conducting exploratory studies and providing educated recommendations.

Keywords: Software Startups · Technical Debt · Pivoting

1 Introduction

Technical debt (TD) has become a practical problem in software practices in the past decade. Software startups encounter TD challenges in different life-cycle phases because product compromises are always needed to meet urgent demands. Most software engineering compromises influence the accumulated "debt," which

needs to be paid at some point in time to assure long-term project sustainability [7]. Facing TD is becoming even more of an urgent need for many software startups [21, 5]. Such startups are known to accumulate TD during their transition from the early phase to the growth phase.

Pivot is a common phenomenon in different stages of software startups, where the companies change the course of actions to survive or grow further. We mainly attribute pivoting at an early phase to startups' desire to explore potential products, measure market effects, and learn from the results. Startups face significant challenges in overcoming TD [5, 13, 1] and pivoting [16], especially in the growth phase. Previous authors emphasize that having less technical debt could give a startup more room for pivoting and product evolution in the long term [13]. TD affects startups' quality and productivity when they shift to the growth phase with stable resources [12]. TD hinders the maintainability and evolvability of software. In turn, TD can commence pivoting, leading growth-phase startups to significant challenges. There is little empirical evidence relating pivoting to TD during a startup's transition to the growth phase.

The aim of this paper is to investigate how TD affects pivoting in growth-phase startups, thus identifying TD processes in different pivoting scenarios. We formulated the following research questions (RQs):

RQ1: *How does technical debt influence pivoting in growth-phase startups?*
RQ2: *How are technical debt processes associated to pivoting types in growth-phase startups?*

Based on the available literature on TD and pivoting, we first provide an analysis of the pivoting dilemma in growth-phase startups. Then, we interview growth phase startup practitioners about their approach to coping with TD and their perceptions of how TD affected pivoting while transitioning to the growth phase. Combining these findings, we categorize the influence of TD on pivoting and the growth phase TD processes in pivoting scenarios. The different categories we identify in this paper are based on the pivoting concepts in software startups [4] and our experience in growth-phase startups' TD [5, 8]. Specifically, we identify three manners that TD influences pivoting in growth-phase startups: (1) direct, (2) indirect, and (3) no-influence. Managing and avoiding technology debt significantly reduces the likelihood of technology pivoting and restrains indirect effects on other pivoting types. Moreover, we propose several hypotheses that suggest exciting new research areas on TD and pivoting relationship theories.

The rest of the paper is structured as follows. Section 2 presents research background. We present our study's design and methodology in Section 3. Section 4 presents the results and key findings. Section 5 discusses the findings. Finally, Section 6 concludes the study and identifies opportunities for future work.

2 Background and Related Work

2.1 Growth Phase Startups' Pivoting: A dilemma

Recently, startup research has proliferated as a subfield of software engineering. In this subfield, although Bajwa et al. [4, 3] have conducted several studies exploring the practices of pivoting in early phase startups, research that includes pivoting—especially in growth-phase startups—is still in its infancy. We observe a lack of proposals on good versus bad practices when startups need to pivot in relation to startup phases and pivoting types. Many authors seem to agree with the idea provided by Terho et al. [20] that pivoting mainly occurs in the early phase; according to these authors, once the business model is established, fine-tuning is more likely to take place.

Based on Muzellec et al. [15], the transitions of startups from one stage to another can be characterized under different categories. Finance is one of the most important factors for startup survival. In the early stages, funding is commonly based on selfcontributions, in the form of self-investment (by bootstrapping between jobs) or loans (from relatives or friends). Other funding options in the early stage of startup formation can come from pre-seed or crowdfunding. In later stages, when a Minimum Viable Product (MVP) has been developed and iteration with the market is a must (do-or-die approach), the need for larger funding amounts from venture capitalists (VCs) and angel investors (AIs) becomes obvious. Finally, if the startup has developed a fully operational product or service, then the market, either local or global, decides the startup's growth potential. After successfully growing in the market startups transition to a more mature phase, resembling more an ordinary company.

The transition of startups is also marked by shifting the startup strategy and the methodological evolution from ad-hoc or customized development practices [17] to more principled approaches. Strategical and methodological changes signify pivoting of the startup, which might drastically change the whole company. According to Ries [17], a pivot is a *"structured course correction designed to test a new fundamental hypothesis about the product, strategy, and engine of growth."*. Pivoting allows startups to continuously improve an idea through product creation and a validation loop. A startup pivots due to a need to shift its strategy to accommodate changes in industry or technology, customer needs, or factors that impact its triple bottom line. Direct and indirect feedback gathered in the product validation phase facilitates the startup pivoting process. Ries [17] presents ten different types of pivoting (Zoom-in, Zoom-out, Customer segment, Customer need, Platform pivot, Business Architecture, Value Capture, Engine of Growth, Channel Pivot, Technology Pivot).

There is only one study that addresses pivoting at various stages of the startup lifecycle (including the growth phase) by Nguyen-Duc et al. [16]. The authors provide evidence that pivots can happen in different phases of a startup's lifecycle. However, the discussion of pivoting in growth phase is relatively brief. Several other studies have addressed software startups' pivoting with a primary focus on early-phase startups [10, 6, 20, 3]. Giardino et al. [9] explores pivoting in

early phase startups while attributing startup failure to the neglect of pivoting. Similarly, studies from Bosch et al. [6] address pivoting at early-stage software startups. The study attempts to relate pivoting decisions to architectural decisions. Terho et al. [20] state that pivoting influences the hypotheses in the lean canvas model. The authors claim that pivoting typically happens early in the startup's life. Bajwa et al. [4, 3] provides an overview of startups' pivoting factors at the early stage, which are mainly attributed to technology and customer segments. The number of experimentation loops is higher in startups' early phase, significantly decreasing in the growth phase. Pivoting in growth-phase startups becomes more of a practitioners' dilemma, and very few studies have addressed the topic. As a startup matures, pivoting is a challenge that involves higher risks.

2.2 TD and Pivoting in Growth Phase Startups: A Preliminary Analysis

Recently, Avgeriou et al. [2] stated: "The term technical debt refers to delayed tasks and immature artifacts that constitute a 'debt' because they incur extra costs in the future in the form of increased cost of change during evolution and maintenance.". Software startups typically encounter TD challenges in different lifecycle phases because product compromises are always needed to meet urgent demands. Most software engineering compromises influence the accumulated "debt" that needs to be paid at some point to assure long-term project sustainability [4].

Another recent study has argued for the need for models, frameworks, methods, and tools to track and manage TD [14]. However, few studies have presented empirical evidence related to TD perceptions in startups. Two in particular focus on TD perception in early-phase startups [11, 1]. A more recent study uncovers four perceptual dimensions of TD (ignore, accept, avoid, and manage) in growth-phase startups [8]. Studies on startups' pivoting and its relationship to TD are scarce. One in particular argues that having less TD could give a startup more room for pivoting and product evolution in the long term [13]. However, the study provides no evidence of how TD is related to different pivoting scenarios in various startup lifecycles. Of these two studies, the first focuses on an innovative perspective of various TD perceptions [8] and the other [13] concerns the relationship between TD and pivoting. We thus argue for the need to deepen understanding of the influences of TD and pivoting.

3 Exploring the practitioners' point of view

To conceptualize the role of TD in software startups' pivoting, we interviewed chief executive officers (CEOs) with extensive experience in software practices. We focused our questions on identifying how they perceived TD in relation to ten pivoting scenarios.

3.1 Case selection

We primarily collected data from startups located in Norway and Brazil. We selected the sample population using the purposive sampling technique. Purposive sampling is a form of non-probability sampling in which researchers rely on their judgment when choosing members of the population to participate in their study [19]. To conduct our study, we purposively chose startups that are in the growth phase. The primary motivation of our choice is because reaching growth signifies that the startup has faced and overcome significant challenges, some of which leading to pivoting scenarios. Some criteria we used to select our startups are: (1) startup was in series A financing; (2) up to 5 years old product commercialization; (3) entered the growth phase in the last 2 years; (4) self-owned or independent headquarters; (5) positive return income in the past 2 years;

3.2 Case Demographics

Specifically, we interviewed six CEOs and five CTOs with more than four years of hands-on experience with software engineering practices in their respective startups, Table 1. Notably, all startups are in the growth phase, and all the interviewees are co-founders of their startups, with active roles in product lifecycle development.

3.3 Interview design and data collection

We performed an empirical study on multiple startup cases based on an interview template for data collection. Writing the interview questions beforehand allowed us to focus our interview questions in connection to the RQs.

The interview process took place in three parts. In the first part, the interview questions primarily addressed demographic information about the startup (duration: 5–10 minutes). The second part focused more on a broad context of the software and technological aspects of the startup (10–15 minutes). The third part concentrated on the perception of TD and its relationship to pivoting (30–40 minutes). We focused the last part of the interview on two key questions that help answer our RQs:

- How have you coped (involving four processes such as ignored, accepted, avoided, managed) with TD while transitioning from the early phase to the growth phase?
- How has TD affected the pivoting (selecting one or more of the ten pivoting types) of your startup while transitioning to the growth phase?

One author obtained the answers from seven startups located in Norway and another from four startups in Brazil. Transcription and data analysis were conducted separately by two authors, followed by discussions and disagreement resolutions with the rest of the co-authors.

Table 1. Software startups' sample demographics.

Startup Case #	Role	Country / City	Product / Service	Founded / Commercial	Clients
Startup 1	CEO	Norway / Trondheim	SaaS - Real Time planning for the Ocean Space	2012 / 2015	30+
Startup 2	CEO	Norway / Trondheim	Privacy and cybersecurity tools	2015 / 2016	50+
Startup 3	CEO	Norway / Trondheim	web based digital retrospectives	2016 / 2017	20+
Startup 4	CEO	Norway / Trondheim	Platform for organizing and sharing information on the internet	2018 / 2019	10+
Startup 5	CEO	Norway / Trondheim	3D vision cameras and software for next generation robotics	2017 / 2018	100+
Startup 6	CEO	Norway / Oslo	Optimal wind farm layout services based Google PaaS	2015 / 2017	80+
Startup 7	CTO	Norway / Oslo	Real estate business intelligence	2017 / 2019	70+
Startup 8	CTO	Brazil / Sao Paolo	Fintech company offering accounting services.	2012 / 2015	60+
Startup 9	CTO	Brazil / Bahia	Legal assistant offering data based on API web services	2014 / 2016	100+
Startup 10	CTO	Brazil / Sao Paolo	Fintech working on prepayment of credit card receivables	2016 / 2016	40+
Startup 11	CTO	Brazil / Bahia	Energy SaaS to support SMEs' contracting of energy	2019 / 2019	1000+

3.4 Data Analysis

First, we carefully transcribed data to obtain significant evidence that would help us answer our research question. We then used the thematic analysis approach [18]. The coding process consisted of identifying recurring patterns and themes within the interview data. The steps to conducting the systematic analysis consisted of the following: (1) **Reading the transcripts.** This step initially involved quick browsing and correction of the automatically transcribed data from the audio recordings. (2) **Coding.** During this step, we focused on choosing and labeling relevant words, phrases, or sentences and even larger text fragments or sections related to TD phenomena. (3) **Creating themes.** After gathering all the codes, we decided on the most relevant ones and created different categories or themes; (4) **Labeling and connecting themes.** We decided on which themes were more relevant and defined appropriate names and relationships for them; (5) **Drawing the results summary.** After deciding on the themes' importance and hierarchy, we generated a summary of the results (cf. Section 4) and discussed them in relation to previous studies (cf. Section 5).

4 The relationship between technical debt and pivoting in growth phase startups

We identified several factors that influenced how the CEOs and CTOs of the startups perceived TD's influence on pivoting while transitioning to the growth phase. In Figure 1 we provide a detailed overview of the thematic analysis summarized into two major groupings, which are as follows: (1) TD's influence on the pivoting type and determining factors (Section 4.1), and (2) TD processes in pivoting scenarios and corresponding considerations (Section 4.2).

Based on the practitioners' answers, we grouped the implications of TD for pivoting into three types—TD directly influencing pivoting, TD indirectly influencing pivoting, and TD not influencing pivoting—each helping to answer our RQ1. Direct effects, as the name suggests, deal with the direct impact of TD on pivoting when not determined by other factors. Indirect effects can be defined as the impact of TD on pivoting determined by other factors. We define a lack of influence when pivoting is not impacted by TD, whether directly or indirectly. Moreover, we map TD processes (managing and avoiding) occurring in growth-phase startups to pivot types—helping to answer our RQ2. In Sections 4.1 and 4.2, we provide a detailed explanation of the relationship found between TD and pivoting.

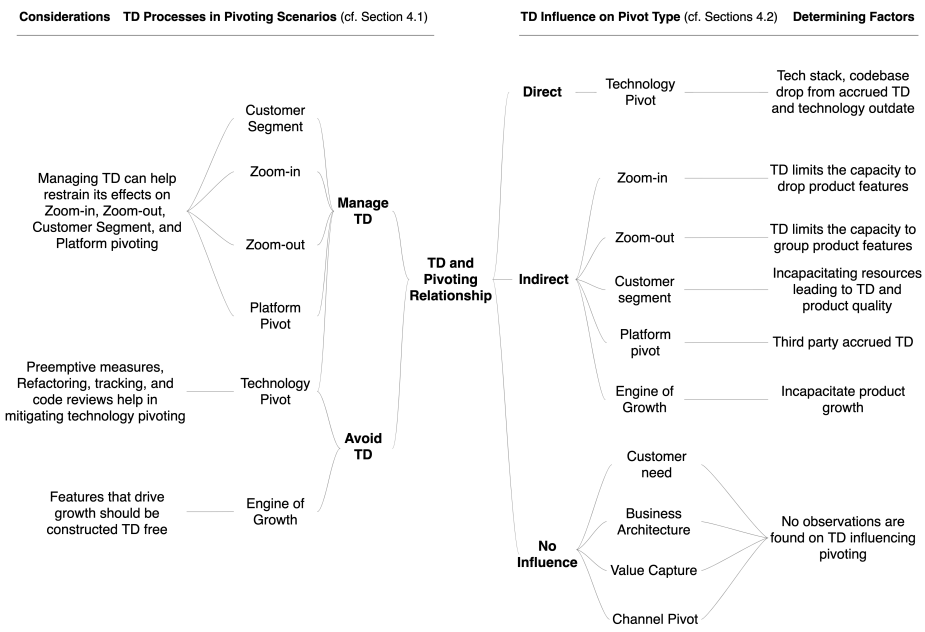

Fig. 1. Thematic analysis of TD relationship to pivoting in growth-phase startups.

4.1 TD influence on pivoting types

TD directly influencing pivoting TD can have a direct influence on pivoting. Specifically, two of the practitioners described a direct influence of TD on technological pivoting. The practitioners reported over ten years of tech experience, and one had co-founded over fifteen startups. They argued that accruing TD leads to an inevitable technology pivoting scenario. Both practitioners claim that accruing TD within their products has led to entire tech stack and code base replacement. Specifically, the CEO from startup 1 reports:

"...Yes, so we've done a couple of technology pivots when we started out ... we could say that we're on the third iteration of different technology at the moment ... Yes, you could say it is because of technical debt ..." ***[Quote 1 - Startup 1]***

Whereas, one CEO states the following:

"...But that platform couldn't really do what we do today...so we basically had to redo the whole platform because of all the technical debt..." ***[Quote 2 - Startup 3]***

A TD induced technology pivot might cause challenges (as will be discussed later) but generally leads startups toward sustainable technology solutions. This means that products can better accommodate more features with a more robust tech stack.

"...With our technology stack right now, we can push new features a lot faster, it is much easier to change things around..." ***[Quote 3 - Startup 2]***

Practitioners supported the idea that TD is inevitable, and that technology becomes outdated with time. Thus, at least a partial technology pivot is likely to happen in the development of every startup.

"...I think for our product changes will happen, no matter what, and technical debt will happen, so our code needs to be changeable as well..." ***[Quote 4 - Startup 3]***

"...But that's the problem with technology so technology is almost like a fashion ... and in the end it's all about choosing tools and a platform that has enough support in the community and thus help avoid technical debt ..." ***[Quote 5 - Startup 1]***

Key findings:

- Technology outdate certainly leads to a technology pivot.
- TD can lead to a technology pivot long before the technology becomes outdated because startups will continuously struggle to accommodate new product features.

TD indirectly influencing pivoting Specifically, two practitioners described the indirect influence of TD on zoom-in, zoom-out, customer-segment, and platform pivoting. Both practitioners had over four years of hands-on experience in business and software development, with one having extended professional knowledge of agile practices. According to both practitioners, TD can hinder a startup's capability to drop or adopt features, which in turn contributes to zoom-in or zoom-out pivoting, respectively. One of the practitioners states the following:

*"...I'd say indirectly, yes, it **[zoom-in pivoting]** is related to technical debt, but not that much that technical debt that we have already fired but more about avoiding future technical debt we prefer to stick to one particular functionality ..." **[Quote 6 - Startup 4]***

Another example provided by one of the practitioners is the fact that in complex systems, the usage of third-party solutions might increase the risk of TD from other developers external to the startup. The utilization of third-party solutions contributes to product limitations encouraging platform pivoting. One of the CEOs reports the following:

*"...it's connected to other people's technical debt. Well kind of looking at it in relation to those other systems ... you could also say technical debt is there and can be related to switching our system..." **[Quote 7 - Startup 6]***

Furthermore, unexpected customer-segment pivoting might push resources away from development teams, which in turn leads to accruing further TD that influences the outcome in reaching new customers with successful software products.

*"...because we changed from B2B to B2C sales take so much resources from our team and it means that I have to do sales, rather than programming and coding and creating better products..." **[Quote 8 - Startup 4]***

Only one participant reports pivoting in engine growth, which is tightly related to developing and market testing only necessary features and adopting growth hacking. In this case, TD was not directly connected to the pivoting; however, the practitioner claimed that TD being left unchecked could drastically incapacitate the startup from achieving product growth.

*"...We are doing growth hacking ... not developing new features that are not necessarily well thought out... but then we are avoiding technical debt..." **[Quote 9 - Startup 1]***

Key finding:

- TD can hinder startups' software development or product growth capabilities, and consequently, become an indirect contributor to technological and non technological pivoting.

TD not influencing pivoting None of the practitioners presented any connection between TD and customer need, business architecture, value capture, or channel pivoting.

Three of the practitioners (Startup 5, 8 and 9) did not observe any direct or indirect connection between technical debt and any of the pivoting types. Only one of the startups argues that the connection of TD with pivoting is beneficial at the early phase to obtain a proof-of-concept. However, this finding is anecdotal for our research and helps little in understanding the role of TD now that the startup is in growth phase:

*"...We are doing growth hacking ... not developing new features that are not necessarily well thought out... but then we are avoiding technical debt..." **[Quote 10 - Startup 10]***

Key findings:

- No practitioners have been able to find an obvious relationship between TD and business-oriented pivot types.
- About 30% of growth-phase startups do not report any direct or indirect influence of TD on pivoting.

4.2 TD processes in pivoting scenarios

Based on the reported analysis of the relationship between TD and pivoting and the practitioners' answers, we can map pivoting types according to TD processes. As discussed with the practitioners, this can help in mitigating the role of TD in startup pivoting. According to Cico et al. [8], we observe two main TD processes in growth-phase startups: managing TD and avoiding TD. In contrast, early phase startups lean more towards ignoring or accepting TD.

Managing TD and pivoting: Managing TD, as defined by Cico et al. [8], includes recognizing, analyzing, monitoring, and measuring TD. Managing TD is perceived by practitioners as beneficial in delaying technology pivoting. Practitioners considered practices such as refactoring, TD tracking, and code reviews to aid in mitigating technology pivoting.

"...We track it, you cannot commit any technical debt to the repository without adding a comment in the code that this is technical debt and track it in a Jira issue...we want to keep our technology stack operational as long as possible..." ***[Quote 11 - Startup 3]***

"...lot of sort of prototyping turned into production software that tends to generate technical debt and that cost us to spend some efforts on refactoring ... we can then push pivoting in time..." ***[Quote 12 - Startup 2]***

However, one of the practitioners claimed that in particular cases, technology becomes outdated and so managing TD might not be the right solution. The interviewee leaned more toward the option of choosing a long-standing technology (Node.js or Python) to delay technology pivot. Two practitioners report the following:

"...choose something ***[Node.js]*** *that we can live with for a while and to manage that technical debt and the risk involved..."* ***[Quote 13 - Startup 3]***

"...The restrictions that we had with previous technology in distributing and managing of the spreadsheets ... was deciding role for changing direction and moving to Power Bi ... and we will stick to the technology for features it has been offering ..." ***[Quote 14 - Startup 7]***

"...Now we use Python, as I told you. And our definition is based on the concepts of Clean Architecture ... We need to reduce the technical debt to evolve the system ***[avoid technology pivoting]*** *..."* ***[Quote 15 - Startup 11]***

Yet another practitioner supports the argument and considers technology as fashion *(cf.* ***Quote 5 – Startup 1)***; in the end, is all about choosing the latest technology with the most community support. In doing so, it is easier to maintain or avoid technical debt and, in turn, technology pivoting.

Practitioners also reported a positive association between managing TD and cases where TD has an indirect influence on pivoting *(cf. earlier analysis)*. Specif-

ically, properly managing TD can lead to smoother transitions in choosing a specific feature to be the basis of the entire product *(zoom-in)* or many features to become a single product *(zoom-out)*. Practitioners made a similar consideration for platform and customer segment pivoting, where TD management can help restrain its effects.

Avoiding TD and pivoting: Avoiding TD is defined by Cico et al. [8] as a proactive strategy to identify all potential software cycles (production–test–release) where TD can occur and to take measures for preventing it. Avoiding TD is typically a burden put on developers when technology pivoting is not an option at a mature startup stage. One practitioner claims the necessity of immediately adopting state of the art toolchains which help in avoiding TD and in turn abrupt technology pivot:

"...We also have a big focus on moving forward when it comes to tool chains...whenever there's a new version of a tool chain, we jump on it immediately, so we can get small increments... instead of switching our code base to a new one..." ***[Quote 16 - Startup 6]***

For several other practitioners avoiding TD-similarly to managing TD-is bound to the technology choice, but with more scrupulous measures-such as code generalization-performed ahead and the adoption of best practices only. The proper technology choice delays technology pivot which in turn can trigger less TD (an observation brought as an opposite argument to the original question asked but demonstrates the strong bond between TD and pivoting).

"...I might with this [pivoting] be stretching it to our product UX...We are generalizing, yeah we're keeping it general, which is a way to avoid technical debt as well..." ***[Quote 17 - Startup 3]***

One practitioner reports the actual connection between avoiding TD and engine of growth pivoting where implementation of necessary features that drive growth should be constructed TD free *(cf.* ***Quote 9 – Startup 1****)*.

Key finding:

- Managing and avoiding TD significantly reduces the likelihood of technology pivoting and restrains effects on other indirect effects of TD in pivoting.

5 Discussions

5.1 TD influence on pivoting in growth-phase startups

In our study, we focus on highlighting the influence of TD on pivoting in software startups transitioning to the growth phase. Although we have a limited number of participants, our study's qualitative nature permitted us to obtain legitimate results that focus on deeply understanding the influence of TD on pivoting. Although this study focuses on a particular niche context, namely, startups transitioning to the growth phase, our results reveal unnoted differences

from previous studies. Thus, we can offer practitioners and researchers unique insights. Nevertheless, this study has limitations as discussed in Section 5.3.

Previous studies have focused on uncovering and addressing TD influence on pivoting in early-phase startups only [4]. We focus more on investigating how TD influences growth-phase startups. We argue that our investigation is of interest because of the following: (1) the TD influence on pivoting is understudied in previous research [12, 4, 8, 9, 6, 20, 3], and (2) we observe the need for startups to consider at least one pivoting type to keep up with the market's evolution. However, if pivoting occurs because startups cannot overcome TD thresholds, then there is a high impact on startups' overall success [5]. In growth-phase startups, failure leads to greater socio-economic impacts.

Our findings enable us to emphasize three ways by which TD influences pivoting. Specifically, we found that TD can have a (1) direct, (2) indirect, or (3) no-influence on pivoting. The line is very thin between the influence and no-influence of TD on various pivoting types related to technology and business activities. We also push our efforts further in mapping TD processes (management and avoidance) in growth-phase startups with pivoting types.

We learn from our results that the discussion on whether TD has any influence on growth-phase startups' pivoting is not sterile. Early studies have provided marginal arguments on TD influence on pivoting [13, 1], specifically focusing on early-phase startups. The reasons for this may vary, but we argue that the research community has yet to reach maturity in TD in general and on its influence on pivoting in particular.

5.2 Benefit to researchers and practitioners

Researchers can benefit from our study in the following ways: (1) by having better insights on how TD influences various pivoting types in growth-phase startups, (2) by mapping different TD processes to pivoting types, (3) by collecting similar data that could help in surveying the startups' TD and pivoting relationship in various startup lifecycle phases, and (4) by providing guidelines/recommendations on how to cope with pivoting influenced by poor TD approaches for startups in various development phases. Practitioners can benefit from our study in the following ways: (1) Consolidating their perception of TD influence on pivoting. Three influence manners can be identified (direct, indirect, and no-influence). We also uncover TD processes that allow understanding of TD's influence on various pivoting types. Consolidation can help startups choose among the best practices in coping with TD influence on pivoting in different startup development phases; (2) Learning to adopt TD processes efficiently, which can help restrain unexpected pivoting scenarios; (3) Understanding when TD can become a risk that leads to technology-related pivoting and when it actually can help startups achieve their market goals without the necessity to pivot.

5.3 Threats to validity

This study is prone to limitations owing to its qualitative nature. However, our intention is not to generalize but rather deepen our understanding on the relationship between TD and pivoting, which is often overlooked by most researchers.

According to Suri [19], the threats to validity in qualitative research are primarily related to the following: (1) **External Validity.** External threats to validity in qualitative studies are related to the sample size and limited context under consideration. We admit that due to the limited number of cases larger sample size is required to generalize the results. To mitigate this threat to validity, we plan to recruit more samples and interview other roles in the startups *(follow-up interviews and questionnaires)*; (2) **Internal Validity.** Internal threats to validity in qualitative studies are related to data extraction and analysis. To mitigate this threat to validity we have carefully coded and categorized the transcriptions while gradually summarizing our findings from the most significant data; (3) **Construct validity.** In our cases, is related to previous knowledge about TD. The maturity level of the startups proved that they were all familiar with the concept. We used an instrument similar to previous research instruments in investigating TD, although applied with a different investigation scope and lenses. Consequently, we argue that this threat to validity is almost non-existent; (4) **Descriptive validity.** Although we have tried to gather as much information as possible, we admit that some aspects might not have been covered. To mitigate this threat to validity, we have used audio recordings of the interviews to verify the descriptive data back in time and stored the rest of the data electronically.

5.4 Hypotheses

Conducting interviews on a small sample in two distinct countries helped us reduce the bias of the obtained results, although fully eliminating them is not possible (cf. Section 5.3). Based on these results, we draw five hypotheses, thereby completing the first half of our investigation. We intend to corroborate our hypotheses by: (1) Conducting questionnaire surveys with a large sample of growth-phase software startups, including the ones that participated in the interview process, and (2) Performing triangulation with artifact analysis of our findings. While identifying the relationship between TD and pivoting, we can make assumptions (hypotheses) worth investigating in the research community.

Hypotheses:

H1: The influence of TD on technology pivot is direct and unequivocal. (cf. Section 4.1)

H2: TD accruing leads to technology pivot at some point. (cf. Section 4.1)

H3: TD has an indirect influence on both technological and business pivoting. (cf. Section 4.1)

H4: TD is not related to business-oriented pivot types (cf. Section 4.1)

H5: Managing or avoiding TD reduces its direct or indirect influence on various pivoting types (cf. Section 4.2)

Startups' lifetime usually does not outpace the core technology used or the tech stack. In H1 and H2, we argue that TD in growth-phase startups has a direct influence and higher impact on technology pivot than the technology outdate. As reported in our findings, accommodating new features that are highly in demand in the market may become practically impossible because of the accrued TD, leading to a technology pivot. Researchers can corroborate both hypotheses based on more quantitative data, enabling practitioners to make educated decisions about resilient technological choices (e.g., tech stack and code base).

In H3, we do not rule out the potential indirect influence that TD might have on various pivoting types, which is also reflected in the summary of our analysis in Figure 1. For instance, zoom-in, zoom-out, customer-segment, platform pivot, and engine of growth are some of the pivoting types that are indirectly influenced by TD. Reasons for this vary from limitations in startups' own or third-party product code to incapacitated resources or business growth, as indirectly affected by TD. By gathering further empirical evidence, researchers would be able to corroborate and eventually discover more factors that lead to the indirect influence of TD on various pivoting types.

In H4, we argue that in some cases, pivoting choices are only related to business activities, such as customer need, business architecture, value capture, and channel pivot. This is why none of the startups could connect TD to business-oriented pivoting, and in particular, around 30% of the startups could not connect TD to any pivoting type at all. Researchers can gather further evidence from a quantitative perspective, which would help uncover the extent to which pivoting is related to TD from a technological perspective or business activities.

In H5, we suggest that such activities as TD management and avoidance, which are often encountered in growth-phase startups, can mitigate the overall effects of TD on pivoting. Especially, as illustrated in Figure 1, technology pivoting is closely related to both TD management and avoidance. Likewise, customer-segment, zoom-in, zoom-out, and platform pivot types are related to TD management, and only the engine of growth pivot type is related to TD avoidance. We observe that managing TD helps restrain various technology-related issues, and thus, undesired technological pivoting. However, if the startup is expected to have healthy product growth, it should take adequate measures to avoid TD. Researchers can deepen the understanding of TD management and avoidance with pivoting by relying on this and previous research [8].

6 Conclusions and future work

We explored how startups perceive TD influence on pivoting in the growth phase. After interviewing six CEOs and five CTOs from eleven software startups from two countries, we identified three ways by which TD influences pivoting: 1) direct, 2) indirect, and 3) no-influence. TD influence on technology pivoting is direct and unequivocal. Nevertheless, growth-phase startups commonly adopt new technologies if they foresee the benefit of such technologies in easily accommodating product features. We also find that TD can hinder the development

capabilities of startups, thus leading to technological and non-technological pivoting. Moreover, we argued that outlier startup cases exist, where pivoting is not related to TD. However, the startups might have pivoted because of other factors before TD actually played any particular role in their pivoting decision. We also do not know if growth-phase startups can avoid TD-induced pivoting by simply managing or avoiding TD.

It will be worthwhile for both researchers and practitioners to investigate and validate our claims. Nonetheless, our findings spark an intriguing debate on the influence of TD on pivoting when startups have reached their growth phase. Our study can help improve startup awareness about the TD processes (e.g., management or avoidance) that startups need to adopt as preemptive pivoting measures. Our results reflect patterns encountered in growth-phase startups. In conclusion, startup research has matured sufficiently in categorizing pivoting and TD processes but has not yet related one to the other. The orthogonal nature of the relationship between TD and pivoting seems to suggest exciting new areas of TD and pivoting theories.

We urge for this topic to receive the attention it deserves in the research community. Our proposed hypotheses merits further investigation in qualitative and quantitative studies. In the future, we plan to collect more data by surveying and interviewing a larger sample. The triangulation will allow us to generalize our findings and provide a clear roadmap and guidelines to be exploited by the research and practitioner community actively participating in software startups.

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