DIGITALIZATION AND DELEGATION:

A STUDY OF STARTUP LIFE CYCLE THRESHOLDS IN THE DIGITAL AGE

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ABSTRACT

Threshold models in the organizational life cycle of startups suggest that founders decide to delegate decision-making authority when they are overloaded, freeing time and attention for strategic decisions. Yet, our theoretical understanding of conditions driving delegation decisions remains limited. We propose that the startup's degree of digitalization influences the propensity to delegate, as digitalization dramatically increases the amount of information available to founders. They become aware of emerging opportunities and areas that requiring attention, making it easier to assess when delegation is appropriate. Using linked employer-employee and survey data from 1,438 startups in Germany, we find support for this hypothesis. Our results also show that the digitalization-delegation relationship intensifies when founders lack managerial experience and startups are larger while it weakens when startups are innovative.

Keywords: digitalization, startups, delegation of decision-making authority, professionalization, information processing

INTRODUCTION

All firms go through an inevitable transition in their life cycle from entrepreneurial management suitable for the start-up phase to increasingly professionalized management thereafter (Daily and Dalton, 1992). Management theory pays particular attention to firms at these life cycle thresholds because the professionalization of management (or its neglect) has far-reaching consequences for the governance of the firm (Gedajlovic, Lubatkin, and Schulze, 2004) as well as its ability to learn and innovate (Zahra and Filatotchev, 2004; Zahra, Filatotchev, and Wright, 2009). The earliest step in the professionalization of management in most startups is the founders' decision to delegate decision-making authority to others (Colombo and Grilli, 2013; Grimpe, Murmann, and Sofka, 2019) which can free up the founders' time and attention for the startup's most strategic decisions (Gifford, 1992; Acs and Gifford, 1996). At the same time, our theoretical understanding of the conditions under which founders make the decision to delegate authority to dedicated managers is not well developed. Indeed, this particular decision is information-intensive because founders must weigh the fixed costs of dedicated managers against (a) the efficiency benefits they bring to the startup's operations and (b) the benefits of freeing up founders' attention for other activities. These assessments are difficult to make in the typical startup context, where resources are scarce, the competitive environment is dynamic, and hierarchies are flat. Consequently, founders likely delay delegation until they are severely overloaded, unless they have access to information that allows them to consider the benefits of delegation more systematically.

In this study, we focus on a particular aspect of information availability within startups that motivates founders of certain startups to begin delegating decision-making authority to dedicated managers earlier than others. More specifically, we focus on the startup's degree of digitalization – defined as processes and technologies for data collection, generation, and analysis (Lanzolla, Pesce, and Tucci, 2020) – that changes the amount and quality of information available to founders. Startups are heterogeneous in the degree to which they are digitalized in their operations. Most modern startups rely on digital tools and platforms for communication and coordination but some are at the forefront of digitalization, using digital

tools and new technologies such as cloud computing, smart sensors, or artificial intelligence (AI) for applications such as market research (Brynjolfsson and McAfee, 2014; Raisch and Krakowski, 2021) or data analysis (Nambisan, 2017; Balsmeier and Woerter, 2019). We integrate mechanisms from this stream of research on the digitalization of organizations into theoretical models explaining the decision of founders to begin delegating decision-making authority to managers (Tushman and Nadler, 1978; Colombo and Grilli, 2013). In our reasoning, digital tools and systems not only have the primary function of performing a specific task, such as communicating with customers, but they also shape the overall availability of information within startups. As startups become more digitalized, founders have comparatively more information available about emerging entrepreneurial opportunities as well as areas of the organization that require their immediate attention. They become aware of opportunities that they would otherwise have missed, as well as problems that they would otherwise not have addressed. As a result, we hypothesize that they are better able to assess the benefits of delegation and begin to delegate decision-making authority to managers earlier than less digitalized startups. In other words, they move their startup out of the initial startup phase and take the next step in the firm life cycle.

We then examine three moderating factors to isolate the information availability mechanism central to our argument. First, we suggest that the effect of digitalization on the delegation of decision-making authority is stronger when founders lack managerial experience that could have exposed them to the benefits of organizational designs (Baron, Burton, and Hannan, 1996; Cooper, Gimeno-Gascon, and Woo, 1994). Second, we propose that the effect of digital information availability is particularly strong in large startups, which generate more information that may require the founders' attention. Third, we argue that the effect of digital information availability is weaker when information is less reliable in startups that produce innovative technologies and products with high degrees of uncertainty.

Our theorizing builds on prior research, which has often suggested that startup founders' capacity to devote adequate attention to different tasks in the startup is severely strained. Managerial attention is a scarce resource that requires trade-offs in the allocation of attention to different tasks (Ocasio, 1997;

Kaplan, 2011). While established organizations can typically rely on professional managers to solve certain tasks, startups are often constrained by the attention that founders can make available (Wasserman, 2012). If they devote too much attention to managing existing operations, they may lose sight of new opportunities and jeopardize the startup's future viability (Marvel and Lumpkin, 2007; Li *et al.*, 2013; Ahlin, Drnovsek, and Hisrich, 2014). This creates pressure to professionalize early in a firm's life cycle, and one prominent mechanism by which startups can free up founders' attention is by delegating decision-making authority to dedicated managers (Grimpe *et al.*, 2019). These managers typically assume administrative and managerial responsibilities, synthesize and prioritize information for founders, and make decisions autonomously (Baron, Burton, and Hannan, 1999; Colombo and Grilli, 2013). They alleviate the constraints on founders' information processing and decision making, allowing founders to focus on more strategic issues that are important for the entire startup. As a result, existing research concludes that the choice of organizational design is crucial for the success of startups, as it is an important milestone for professionalization and survival (Colombo and Grilli, 2013; Wasserman, 2012). At the same time, the startup conditions that help founders to delegate decision-making authority earlier have been largely unexplored. Our theorizing is a first step towards opening this black box, by introducing startups' reliance on digital tools and systems as a factor supporting this organizational design decision.

We test our theoretical reasoning using a unique sample of 1,438 startups founded in Germany between 2010 and 2015. The information on these firms comes from linked employer-employee data, which merges firm data from a panel survey with official registry data on the founders and employees working in these firms. The registry data systematically cover occupations and allow us to comprehensively track the introduction of occupation codes for dedicated managerial jobs. Our reasoning is informed by a series of semi-structured interviews with startup founders, which help us better understand the opportunities and demands of digitalization and the roles and responsibilities of dedicated managers in such contexts. Consistent with our theoretical predictions, the empirical study shows that increasingly digitalized startups rely on the delegation of decision-making authority relatively early in their life cycle. This effect is stronger when founders lack prior management experience and when the startup is relatively large. It is

weaker when startups are more innovative.

Our findings advance the existing literature in two important ways. First, our research contributes to the literature on the emergence of startup organizational designs (e.g., Foss, Lyngsie, and Zahra, 2015; Grimpe *et al.*, 2019). This literature rarely considers the agency and considerations of founders who begin to delegate decision-making authority (Colombo and Grilli, 2013). We focus on the use of digital tools and systems within a startup as a mechanism by which founders can better understand when their startup would benefit from dedicated managers in certain areas, and which areas benefit from their own attention. According to our theoretical logic, digitalization not only changes the desired skill profiles of firms (e.g., Ritter and Pedersen, 2019) but also the usefulness of organizational designs. At the same time, our theoretical model can be a platform for future theorizing about other conditions that influence founders' decisions about delegation, such as the availability of qualified individuals who could become specialized managers.

Second, threshold models of firm life cycles are central to understanding the necessary management transitions from startups to established firms (Gedajlovic *et al.*, 2004; Zahra and Filatotchev, 2004). Our findings provide a first indication that startups reach these thresholds earlier when they rely heavily on digital tools and systems. We demonstrate this effect for the first step in the professionalization of startup management, i.e., the delegation of decision-making authority by the founders. Then again, our theoretical reasoning, which stems from the digital availability of information for decision making about organizational design, is likely to apply to a broader set of strategic decisions in startup development, such as the creation of hierarchies or the outsourcing of business functions.

THEORY AND HYPOTHESES

Founder attention and the delegation of decision-making authority to dedicated managers

Founders are uniquely positioned to process critical information in startups. Because startups typically go through dynamic periods of rapid change in their environment early in their life cycle, they face many situations that require decisive decisions that could jeopardize the entire firm. Founders can make such decisions with authority and legitimacy because they are typically the dominant shareholders of the startup

(Gedajlovic et al., 2004). These advantages of combining the founder and manager roles are quite persistent and do not diminish until a firm reaches a significant size (Daily and Dalton, 1992; Walters, Kroll, and Wright, 2010). It is not surprising, then, that founders have been identified as the primary source of creativity within the startup (Zahra et al., 2009) and determine virtually every strategic decision (Nelson, 2003).

The unique role of founders in the decision making of their startup places a heavy burden on their ability to devote adequate attention to each task. Managerial attention is scarce in all firms, leading to attentional trade-offs between tasks (Ocasio, 1997; Kaplan, 2011). Larger and older firms benefit from allocating attention to specific tasks among professional managers. Startups, however, rely heavily on the ability of their founders to allocate attention effectively (Wasserman, 2012). The literature on entrepreneurial attention is particularly concerned with founders devoting too much time to managing existing operations at the expense of creative activities (Marvel and Lumpkin, 2007; Ahlin et al., 2014) and developing innovative products or businesses (Li et al., 2013). Given the risks of founder attention overload or misallocation, considerations for a more appropriate organizational design of startups become salient relatively early in the organizational life cycles. For most startups, these considerations begin with the decision of whether founders should delegate decision-making authority to dedicated managers (Grimpe *et al.*, 2019).

These managers are specialized employees with delegated decision-making authority for administrative or managerial tasks (Baron *et al.*, 1999). Within an organizational hierarchy, they are located between the top-level decision makers of a firm, i.e. the founders, and the rank-and-file employees (Rajan and Wulf, 2003). Therefore, when founders start to delegate decision making in a startup, it is a crucial change in the organizational design (Colombo and Grilli, 2013). The central purpose of this delegation is to improve coordination and efficiency while making the organization of work increasingly traceable and predictable (Sine, Mitsuhashi, and Kirsch, 2006).

The context of delegation decisions and the availability of digital information

While delegation is inevitable in most startups, the conditions under which founders make delegation decisions are rarely explained. Because these decisions are information-intensive, founders need to weigh the cost of a dedicated manager against (a) the efficiency gains from delegated decision-making by a manager and (b) the improvement in their own decision-making after delegation. Thus, founders need to assess their own capacity for processing startup information and anticipate how dedicated managers would change it.

The information-processing benefits of delegating decision-making authority can materialize in complex ways. Founders, like all individuals, are limited in their ability to handle information, including gathering, storing, transforming, and transmitting information (Simon, 1948). Dedicated managers can share information processing efforts with founders and improve overall efficiency through parallel processing (Radner, 1993). More importantly, these managers can select and prepare the information for founders that will benefit most from direct founder involvement and decision making. As a result, founders can focus their attention on processing information that is beyond the authority of managers (Garicano, 2000). Thus, founders deal with information that benefits from organization-wide solutions (Harris and Raviv, 2002), while certain operations or businesses become the responsibility of dedicated managers (Gifford, 1992). Ideally, founders can focus on strategic decisions and delegate other decisions entirely to managers (Gifford, 1992). As a result, founders are more likely to delegate decision-making authority when they can more accurately predict the benefits of doing so. We argue that these benefits become comparatively more predictable as startups increasingly rely on digital tools and systems that accumulate a pool of digital information as a basis for anticipating the benefits of delegating decision-making to dedicated managers.

The use of digital tools and systems in startups follows a broader trend of digitalization in the modern economy. Digitalization is a multi-faceted phenomenon that refers to the use of digital technologies in organizations (Nambisan, 2017; von Krogh, 2018), usually based on electronic connectivity through an internal network or the internet (Ritter and Pedersen, 2019). This includes digitalization in production and

service delivery, where production processes and value chain partners, suppliers, and customers are linked through shared interfaces and information exchange ("Industry 4.0") (Brynjolfsson and McAfee, 2014; Faraj, Pachidi, and Sayegh, 2018). Digitalization also includes the use of artificial intelligence (AI) for information processing and autonomous decision making (von Krogh, 2018), big data analytics, cloud computing, or the Internet of Things (Schwab, 2016; Sturgeon, 2019), as well as the facilitation of internal and external communication through internet-based platforms and channels, including the corresponding hardware. In this sense, the extent to which startups use digitalization in their organization can vary from a rather narrow scope, where digital technologies are applied only in a few areas, to a more comprehensive scope, where most activities rely on digital tools and technologies (Ritter and Pedersen, 2019).

Prior literature has described the implications of digitalization for the type of information that increasingly digitalized organizations deal with. Digital technologies enable the collection and analysis of large amounts of information in an effective and efficient manner. Digital applications collect large amounts of data on production processes, interactions with suppliers and customers, or employee performance. This rich data collection enables much more precise tracking and monitoring of all kinds of business activities, increasing the transparency of both processes and outcomes (Faraj *et al.*, 2018). In this sense, digitalization enables comparatively faster and more reliable collection and synthesis of large amounts of information, which is potentially critical for management decisions (Ritter and Pedersen, 2019). Further, digital technologies have become much more "intelligent", for example through machine learning, smart sensors, or data analytics (Lanzolla *et al.*, 2020). Smart technologies can operate autonomously so business operations are becoming increasingly interconnected. This affects integrated production planning, resource allocation, as well as automated flows of goods within and across organizations independent of human involvement (Brynjolfsson and McAfee, 2014; Porter and Heppelmann, 2014; von Krogh, 2018). Hence, information about process or product flows becomes available even when there are no humans involved.

We conclude that founders of startups that rely heavily on digital tools and systems will find it easier to rely on digital information to assess which types of activities consume a lot of their attention without

being strategic in nature and could be better handled by dedicated managers. Founders in startups with limited digital information may find it comparatively more difficult to track information flows that consume most of their attention and to quantify or isolate promising tasks that would benefit from delegation. As a result, these startups are likely to delay the delegation of decision-making authority from founders to managers. In fact, the founder of an education-focused startup describes how digital information enables him to delegate decision-making authority quicker:

> *"I would be able to promote middle managers quickly if I were a digital organization, because as a founder I have a better ability to assess the different parts of our business. […] I think by having the data and knowing that it exists, we've become more data driven".*

The same founder points out an important aspect of the delegation decision, which is assessing whether the benefits of introducing managers with delegated decision-making authority will bear fruit for the startup. With the increasing availability of digital information, these benefits not only become more predictable, but can also be tracked. This is how the founder describes his thinking:

> *"If I were in a non-digital environment, I wouldn't be able to see the result of my middle managers as easily. So I would trust them less, I would probably have to be more hands-on and not need them as much. So basically I can give more responsibility to a middle manager because I can more easily assess whether they are having a positive or negative impact on the area they are managing."*

Taken together, we propose:

> *Hypothesis 1: There is a positive relationship between the degree of digitalization in a startup and the propensity of its founders to delegate decision-making authority to dedicated managers.*

Moderating factors for the effects of digital information availability

Within our logic for Hypothesis 1, a startup's use of digital tools and systems creates a context in which more digital information is available for founders to make delegation decisions. Naturally, founders and startups are heterogeneous in the extent to which they will use this digital information. We explore three

dimensions of these heterogeneities that are directly related to, and help us isolate, the digital information availability mechanism that is central to our argument. Specifically, we examine the moderating effects of founders' managerial experience, the size of existing operations, and the startup's pursuit of innovation.

First, the nature of the founders' experiences is an important determinant for the management of their startups (Dencker and Gruber, 2015). Among these prior experiences, managerial experience is particularly important as it is often acquired in practice during time spent in other firms (Sørensen and Fassiotto, 2011). Founders with prior management experience have learned what activities are required in the startup and how to set them up (Baron *et al.*, 1996; Cooper *et al.*, 1994). In addition, managerial experience allows founders to prioritize some tasks over others (Gifford, 1992), they are likely to be aware of the demands on managerial attention. Because these founders have experience with how tasks are performed in efficient organizations (Dencker and Gruber, 2015), they understand the benefits of delegated decision-making authority. Thus, as a baseline, we would expect founders with managerial experience to delegate decision-making authority earlier than inexperienced founders.

Focusing on the interaction with the degree of digitalization in startups, founders with managerial experience are comparatively less likely to require digital data when they decide to rely on dedicated managers for some areas of the startup. In contrast, founders without managerial experience lack these priors from the organizational design of established organizations. For these individuals, the availability of digital information makes attention overload much more salient. Because they lack a structured understanding of the managerial requirements, the information available from digital tools and systems is likely to lead them to recognize (a) missed entrepreneurial opportunities and (b) areas of the startup that require urgent attention. Thus, for inexperienced founders, the degree of digitalization becomes a much more effective enabling factor for delegating decision-making authority. Consistent with this view, the founder of a fintech startup reflects on the pressures from digitalization and explains how the lack of management experience led him to delegate decision-making authority:

"I think at least from my experience – I have a United Nations background – I have never

managed big things and I have never worked with middle managers. […] Digitalization creates a lot of information. And I'm sure that if you had twenty years of management experience from a consultancy firm or government agency or industry or corporations, you'd probably be better at that than I am. But in our case, since we are both relatively new to management, it is a big challenge. […] So you hire somebody who you think is going to be able to take over this area, and then you hire the team under that person."

In conclusion, we propose the following hypothesis:

Hypothesis 2: There is a positive relationship between the degree of digitalization in a startup and the propensity of its founders to delegate decision-making authority to dedicated managers, and this effect is stronger when founders lack prior management experience.

Second, we focus on the size of the startup's current operations as a condition under which delegation of decision-making authority becomes a more attractive option in startups with a high degree of digitalization. Gifford (1992) outlines the main effect of startup size on founder attention, in which the size of a startups current operations diverts attention away from new product development. Naturally, larger operations create more information processing needs, and delegation is likely to result in positive effects of shared information processing (Radner, 1993) and prioritized decision making (Garicano, 2000; Harris and Raviv, 2002) on founder attention. Thus, increasing size is likely to be associated with delegated decision-making authority.

Focusing on the interaction with digitalization in startups, we expect the effect to be particularly strong in larger startups, where the opportunities from automated data collection, big data analytics or artificial intelligence are high given the volume of data (Sturgeon, 2019). In small startups, founders are comparatively more likely to have an accurate view of relevant information and the capacity to process it, even if the information is not available in digital form. However, as the size of the operations increases, it becomes less likely that non-digitalized information accurately reflects the startup's coordination needs and capabilities. Under these conditions, the availability of digital information is likely to facilitate founders' decision making about areas and functions of the firm that would benefit from dedicated management

with delegated decision-making authority. In line with this view, the founder of the fintech startup argues that digitalization enables the growth of customer relationships while making the complexity of managing these relationships more visible:

> *"We have somewhere between 40 and 60 dialogues going on with potential customers at various stages of that journey. Those dialogues are kept in Outlook, in Excel, in some ways they are sometimes shared with partners. […] [T]his volume of dialogues is only made possible by digitalization, but then of course it also creates a web of complexity, and you need further efforts to basically organize this information because it is highly relevant for us […].*

Thus, we hypothesize:

> *Hypothesis 3: There is a positive relationship between the degree of digitalization in a startup and the propensity of its founders to delegate decision-making authority to dedicated managers, and this effect is stronger when the size of operations is larger.*

Finally, the creation of innovative products and services is central to many startups, especially in high-tech industries (Grimpe *et al.*, 2019). Intuitively, we would expect highly innovative startups to have flat hierarchies and short decision-making paths to facilitate creativity and experimentation, in other words, a less mechanistic and formalized organizational design (Burns and Stalker, 1961). Thus, as a baseline, we would expect innovative startups to delay the delegation of decision-making authority. Focusing on the interaction with digitalization, we argue that the information availability affordance of digitalized startups becomes less relevant for the decision to delegate decision-making authority. On the one hand, innovation activities deserve a great deal of attention from founders since they are critical to the long-term success of a startup. On the other hand, many innovation activities involve considerable uncertainty about their technological or commercial viability (Amit, Glosten, and Muller, 1990), and many founders instead focus their attention on the profitability of existing operations (Acs and Gifford, 1996).

We argue that the inherent uncertainty in the success of innovative products reduces the reliability with which founders can use digital information to assess the benefits of delegating decision-making authority. Big data analytics and artificial intelligence can improve the odds of innovation success (Joshi *et*

al., 2010; Bardhan, Krishnan, and Lin, 2013), but this does not automatically imply that a startup would be better off if founders delegated decision-making authority. The founder of a high-tech startup considers these limitations of digital information for removing himself from decision-making in his innovative startup:

> *"Innovation per se, I think, is something we can't buy or improve through [these digital] tools. I don't think so. We will be faster in what we do and our workload will be reduced, so we will have more space for creative work [...], but the innovation work does not happen because of the tools. They simply allow me to share or test my innovation, design or whatever I have newly built faster."*

In comparison, we argue that the effects of digital information availability on judging the merits of delegation are particularly strong when the startup relies on established technologies and products. Under these conditions, digital information availability may be highly predictive of the areas and functions that would benefit most from dedicated management. Hence, our fourth hypothesis reads:

> *Hypothesis 4: There is a positive relationship between the degree of digitalization in a startup and the propensity of its founders to delegate decision-making authority to dedicated managers, and this effect is weaker when the startup is increasingly innovative.*

DATA AND METHODS

Data

We build a dataset that combines multiple data sources to test our hypotheses. The dataset links firm-level data from the IAB/ZEW Startup Panel with official employment statistics provided by the German Federal Employment Agency to an employer-employee panel dataset. The IAB/ZEW Startup Panel surveys German startups of the cohorts 2005-2018. It was originally established in 2008 as a joint project of the KfW Bankengruppe (Germany's largest state-owned promotional bank), the Centre for European Economic Research (ZEW), and Creditreform (Germany's largest credit rating agency) and has been continued by ZEW, Creditreform and the Institute for Employment Research (IAB) of the German Federal Em-

ployment Agency since 2014. The IAB/ZEW Startup Panel is a stratified random sample of legally independent new ventures drawn from the population of German firms as contained in the Mannheim Enterprise Panel. The Mannheim Enterprise Panel contains basic information on all firms like startup and exit dates, ownership structures, legal forms, and industry classifications (for a detailed description, see Bersch *et al.*, 2014). The sample design of the IAB/ZEW Startup Panel entails a stratification for industries and years of foundation. Stratification is controlled for by including dummy variables for the stratification cells in all regressions. To be included in the sample, firms cannot be older than three years, subsidiaries of other firms or ventures that resulted from merger activities (for a detailed description, see Fryges, Gottschalk, and Kohn, 2010).

Once startups have participated in the survey, they are followed for up to seven successive years. Data collection is performed by computer-assisted telephone interviews. In this study, the survey data provide information about parts of the founders' characteristics (i.e., educational background and entrepreneurial experience) and venture characteristics (most importantly, the use of digital tools).

To obtain more detailed information on the startups' founders and employees, we link the firm-level survey data to employee-level information from official Federal Employment Agency employment statistics. The employment statistics contain registry data on all employees that are subject to social security contributions in Germany and allow combining the social security information to an individual employment biography on a day-by-day level.[1] These person-specific employment registers allow, most importantly, for identifying dedicated managers based on occupation codes (see variable description below for details) and the date when they are hired. The employment statistics also provide additional details on founder and employee characteristics for the purpose of our study.

[1] In addition to regular full-time and part-time employees, this includes apprentices, interns, and marginally employed personnel. All notifications on employment and unemployment spells of an individual can be linked with the help of a unique person-specific identifier, making it possible to obtain the complete employment history of each employee. Another identifier makes it possible to match the employees to establishments.

As there is no common identifier in the two datasets, we match the establishments from the employment statistics to startups from the IAB/ZEW Startup Panel by means of a text search algorithm using startup names and addresses. In addition, we match the founders' previous employment biographies (before starting up their own firms) via founder names and exact birth dates. The text search algorithm has proven to deliver very reliable results in various settings (Czarnitzki *et al.*, 2015). We are able to match about 90% of the startups from the IAB/ZEW Startup Panel that self-reported having employees subject to social security contributions (during a telephone interview) with one or more establishments from the official employment statistics.[2] Firms that self-reported having employees subject to social security contributions, but which could not be found in the official employment statistics, were removed from the sample.

In the present study, we are able to draw on information from 1,438 startups from the cohorts 2010-2015 that answered survey questions on their use of digital tools and reported at least one paid employee until the end of our observation period for the register data in 2017.

Variables

Dependent variable

Our hypotheses predict how the degree of digitalization affects startups' propensity to delegate decision-making authority. We measure the propensity to delegate by the time (in days) between firm foundation and the date of first employing an employee with dedicated decision-making authority. Indicators for the presence of such employees come from occupation codes available in the employment statistics of the German Federal Employment Agency. In the individual level data, occupations are coded using the five-digit occupation code KldB2010 (the German adaption of ISCO-08, devised by the Federal Employment

[2] The name matching of the founders produces a 80-85% matching rate which is within expectations since some founders might not have prior employment records in Germany, e.g. when they have moved from abroad. As a result, we might underestimate the levels of education and experiences in a few founding teams which generates downward pressures on the significance tests in our regression analyses.

Agency). While the first three digits describe the particular functional specialization of an occupation, individuals in occupations with supervisory or executive competences are identified by a "9" as the fourth digit of the five-digit KldB2010 occupation code. We classify individuals with such supervisory or executive competences as those receiving decision-making authority.

Explanatory variables

Our main explanatory variables are a firm's degree of digitalization, whether a founder has experience as manager, the size of a firm's current operations, and a firm's degree of innovativeness.

To measure a startup's degree of digitalization, we resort to survey questions that ask about the startup's use of digitalization in different areas of their operations in the survey of 2017. Startups are asked about the use of digitalization in (1) *production and/or service provision* (digital interconnections within production or service provision, digital interconnection between production or service provision and logistics, digital interconnection with customers, digital interconnection with suppliers or other industry partners, other types of digitalization); (2) *internal organization and communication* (ERP software, web-enabled mobile devices, software-based communication, intranet-based platforms, other types); (3) *distribution and external communication* (own website, e-commerce, product-related apps, social media, others); and (4) *information processing* (cloud computing, big data analyses). Data on each item is available in a yes/no format. For our main dependent variable, we add up all items to an index for the degree of digitalization, ranging from 0 (no item) to 17 (all items). In post-hoc analyses, we differentiate between digitalization in areas that we expect to improve connectivity (i.e. areas (1), (3), and (4) from above) and areas that we expect to support internal coordination (i.e. area (2) from above). Information on digitalization is not available on an annual basis. Instead, it is part of a one-year topical questionnaire on digitalization, which asks respondents to assess the overall degree of digitalization in their startup. Accordingly, the data do not allow for testing dynamic hypotheses but they are adequate for comparing effects between startups in line with our hypotheses. We relax this restriction in the robustness checks section, in which we discuss robustness checks using an alternative measure of digitalization that is generated from the employment histories of startup employees and is available on a continuous basis.

Similar to our definition of dedicated managers among employed personnel, we measure managerial experience of the founders from occupation codes in their employment history before they started their own firm using a dummy variable. The variable on founders' managerial experience takes the value one if anyone in the founding team ever held a position with supervisory or executive competences (i.e. they ever had a "9" as the fourth digit of the five-digit KldB2010 occupation code).

We measure the size of current operations as the full-time equivalent number of employees. We proxy a firm's innovativeness by a variable that adds up the number of new or significantly improved products (or services) introduced between firm foundation and the first delegation decision.

We control for a number of factors that have either been shown to be associated with the likelihood of delegating decision-making authority to employees (Colombo and Grilli, 2013; Grimpe *et al.*, 2019) or that we expect to potentially affect both delegation and the use of digitalization. Table 5 in the appendix provides details on the construction of all variables. We control for differences in human capital quality using two dummy variables for whether at least one of the founders has a tertiary education as well as for whether the firm employs any personnel with tertiary education. We control for the field of founder education by adding two dummy variables for whether at least one of the founders has an education in informatics or in business. Moreover, we add control variables for the average age of the founders, for the number of patents a firm/the founders held before they began to delegate, for whether a firm received any equity capital before delegation, for whether the firm is active in a digital product market, as well as industry and year of foundation dummies (to control for cohort effects in the use of digital tools).

Estimation approach and identification

Since our dependent variable measures the days to delegation, we choose Cox proportional-hazard models with robust standard errors as our main estimation method (Cox, 1972). Because both the use of digitalization and the delegation of decision-making authority are choices of the founders and might be simultaneously determined by the founders' experience and preferences and/or firm performance, endogeneity is a potential issue in our empirical setting. We address the endogeneity concerns with a two-step strategy. First, we pre-balance our sample over a large number of indicators that significantly predict high degrees

of digitalization in a first-stage regression. Second, we control for these and additional factors that might determine the startups' propensity to delegate directly in all (balanced) outcome models. In addition, in the robustness check section, we present alternative specifications in which we use instrumental variable estimates that instrument for the degree of digitalization.

To implement the pre-balancing empirically, we apply entropy balancing. Entropy balancing allows for inducing balance over specified moments (mean, variance, skewness) of selected covariates through sample weights. The derived weights are then used in weighted regressions (Hainmueller, 2011; Hainmueller and Xu, 2013). Entropy balancing can be intuitively understood as the creation of a synthetic control group. For the synthetic control approach, control group observations are re-weighted based on observable characteristics, so that the specified sample moments closely mimic the corresponding sample moments of the treatment group (cf. Abadie, Diamond, and Hainmueller, 2010). The major advantage of entropy balancing over related methods like propensity score matching is that it induces covariate balance directly and not as the result of a propensity score matching procedure that requires iterated re-specifications of the propensity score estimation to achieve covariate balance. Entropy balancing has been used for synthetic control group generation in several recent empirical studies (e.g., Bansak, Hainmueller, and Hangartner, 2016; Malesky and Taussig, 2017; Satyanath, Voigtländer, and Voth, 2017; Grimpe *et al.*, 2019; Distel *et al.*, 2019).

We base our choice of balancing criteria on results of a first-stage regression with a dummy variable for a high degree of digitalization as dependent variable (measured as digitalization values higher than the median startup in the sample). With the help of these first-stage regressions, we attempt to determine potentially endogenous factors that predict both digitalization and delegation (the first-stage results are discussed in detail in the results section). As a result, we balance on dummy variables for whether (at least one of) the founder(s) has managerial experience, whether (at least one of) the founder(s) has entrepreneurial experience, whether (at least one of) the founder(s) has an education in informatics, whether (at least one of) the founder(s) has an education in business, whether the firm offers digital products, as well as industry dummies. In addition, we balance over the average age of the founders and number of product or process

innovations before delegation as continuous balancing criteria. To achieve the best possible balance, we always balance on the maximum number of moments feasible for each variable, i.e., three moments for the continuous measures and one moment for the dummy variables.

As expected, the data show that startups with a high degree of digitalization differ significantly from those with a low degree. Founders of highly digitalized startups are on average younger, more often experienced as entrepreneurs, more likely to have an education in business or informatics, to introduce more innovations, to offer digital products, to be active in ICT sectors, and to receive equity capital funding. After balancing though, original differences are entirely leveled (see Table 6 in the supplementary appendix for results.)

RESULTS

Descriptive statistics

In Tables 1 and 2, we provide summary statistics as well as pairwise correlations and variance inflation factors (VIFs). About 23% of startups delegate decision-making authority to employees while we observe them (327 of 1438). If they delegate, they begin to do so 454 days after the date of foundation on average. The firms use on average 6.62 different types of digitalization. Founders are on average 41.65 years old, 60% of firms are run by at least one founder with a tertiary degree, 28% of firms employ any personnel with a tertiary degree. 43% of startups have at least one founder who gained experience as manager before starting up the own company. In 53% of startups at least one of the founders has prior experience as entrepreneur (i.e., either started an own firm or was self-employed before). Concerning their fields of education, 9% of firms are run by at least one founder with an education in informatics, 33% by at least one founder with a business degree. The firms employ on average 1.70 full-time equivalent employees in the year of foundation, introduce 1.55 products before they first delegate, and hold on average 0.27 patents before delegation. 25% of startups are active in a digital product market. 8 % receive private equity investments before they delegate decision-making to employees for the first time.

------ Table 1 about here ------

------ Table 2 about here ------

The correlations between the explanatory variables do not reach levels that indicate collinearity concerns. This assessment is supported by the Variance Inflation Factors (VIF) of the main model, which have an average value of 1.60 and are hence far below the usually applied critical level of 10 (Belsley, Kuh, and Welsh, 1980).

First stage results for the determinants of a high degree of digitalization

Table 3 shows an exploratory analysis of a high degree of digitalization in startups. The results of the linear probability model for an above median degree of digitalization reveal significant positive correlations between high digitalization and high innovation (i.e., the number of product innovations before delegation). Similar to the results of the entropy balancing, younger founders, founders with entrepreneurial experience, and founders with education in business or informatics are significantly more likely to use digital tools. The same holds true for firms that offer digital products and firms that received equity capital funding before the first delegation.

------ Table 3 about here ------

When we repeat the estimation of the same linear probability model but apply the weights derived by entropy balancing (second model of Table 3), all significant predictors of high digitalization from the first model are rendered insignificant. This indicates the functioning of the chosen balancing approach. As intended, entropy balancing achieves balance between "treated" startups, i.e., with high degree of digitalization, and "control" startups, i.e., with low degree of digitalization, thereby eliminating observable simultaneity biases.

Results of hypothesis testing

Our main multivariate regression coefficients from weighted Cox proportional-hazard models reveal a positively significant relationship between a startup's degree of digitalization and its propensity to delegate decision-making authority to employees (Table 4, first model). This is in line with our reasoning for Hypothesis 1. The effect size is substantial. The coefficient of the degree of digitalization in our main Cox regression equals a hazard ratio of 1.08 (exp(Coef.) = exp(0.077)) which indicates that startups increasing their digitalization index by one digital tool improve their odds of delegation by 8%.

------ Table 4 about here ------

Concerning the effects of the included control variables, most noteworthy, the number of employees, whether a firm employs highly educated personnel, and whether a firm received private equity capital positively and significantly predict the propensity to delegate. In contrast, more innovative firms, with more new products in previous years, are significantly less likely to delegate early.

To test the hypothesized moderating effects on the relationship between digitalization and delegation, we apply interaction analyses (Table 4, models 2-5). In line with Hypothesis 2, we find a negative and significant interaction effect between the degree of digitalization and the dummy variable for whether any of the founders has experience as manager. In other words, founders who lack managerial experience delegate earlier with an increasing degree of digitalization. Interestingly, managerially experienced founders seem to foresee the need for delegation and professionalize earlier in general (positive main effect). Our regression results also support Hypothesis 3 by showing a positive and significant interaction term between the degree of digitalization and the size of the current operations (approximated by the number of full-time equivalent employees). Finally, our estimates support Hypothesis 4. More innovative firms, i.e., the ones that introduced more new products, delegate later when they have a high degree of digitalization (significantly negative interaction effect).

Sensitivity checks and post-hoc analyses

We conduct a number of consistency check estimations and post-hoc analyses (see Table 7 in the supplementary appendix for robustness checks; see Table 8 and Table 9 in the supplementary appendix for post-hoc analyses). First, we explore potential effects from the measurement of digitalization and replace the index variable with a simple dummy variable for high digitalization (above the sample mean of digitalization activities). We find consistent results. Second, we explore curvilinear relationships from the degree of digitalization since extreme values may drive the results. Accordingly, we rely on the continuous measure of digitalization (as in the main models) and add its squared term. We find no evidence for curvilinearity. Hence, modeling the degree of digitalization as a continuous, linear variable in our main estimations is appropriate. Third, for assessing the impact of the balancing approach on our results, we repeat our

main model estimations and the model with the dummy for high digitalization as explanatory variable without applying the entropy balancing weights (i.e., we only control for potentially endogenous factors directly but do not create a synthetic control group). In both cases, significance becomes slightly stronger and effect sizes slightly increase. This effect indicates the appropriateness of the balancing approach for addressing potential endogeneity concerns based on observable characteristics in our setting. Fourth, we also find consistent support for our main results when we model the time to delegation by a linear regression model (note that we impute a high value of 5000 days for firms that never delegate for this robustness check to make the estimation of a linear model feasible).

In further post-hoc analyses, we split the index for digitalization between digitalization in areas that we expect to improve connectivity and areas that we expect to support internal coordination as explained in the data section. While the main effects consistently support the hypothesized relationship that high digitalization is associated with earlier delegation, we find that the significant interaction between digitalization and founder managerial experience is mainly driven by coordination-improving, digital tools. In contrast, the significant interaction with the size of current operations seems mainly driven by digitalization in connectivity. Overall, organizational design choices seem to occur with the need for information processing in digitalized startups, not by any one type of digitalization in particular.

Although our data provide in-depth information on the use of digital tools in startups, they are limited in the sense that the information on digitalization was included in the survey only once, so that we do not have longitudinal information on when exactly digital tools were introduced. This could lead to concerns about reverse causality and other endogeneity issues. To address such issues, we turn to the employment register data to derive an alternative measure of digitalization in startups from the employment biographies of the startups' employees. We use information on whether a startup employs any employees who are dedicated IT specialists when they enter the startup (i.e., those who have previously worked in an ICT occupation according to classifications of the German Federal Employment Agency) as a proxy for the startups' degree of digitalization. This approach follows prior research which has used a human capital based measure of a firm's digital expertise (Grimpe, Sofka, and Kaiser, 2022). Using this proxy allows us

to address weaknesses of the survey data by constructing a panel dataset that contains annual information on digitalization and delegation and that is not restricted to surveyed startups. We use this setup to predict whether the likelihood of delegating decision-making authority increases when startups employ IT specialists.

We find results consistent with our main model results when we model the degree of digitalization as a dummy variable for the presence of at least one IT specialist or as the (log-transformed) number of IT specialists (columns A and B of Table 10 in the supplementary appendix). We also find consistent evidence when we estimate fixed effects models to abstract from any time-invariant heterogeneity across startups, and when we estimate instrumental variables models in which we instrument the employment of IT personnel by (1) the high-speed mobile internet coverage in the startup's region and (2) the likelihood that other startups of the same size and age group employ IT personnel (columns C and D of Table 10). Both instruments are predictive for whether startups digitalize but can be argued to be exogenous to whether they delegate decision-making authority to employees. Tests of the instruments suggest that they are valid (first stage F-statistic >>10 and Hansen's J-test > 0.1). Thus, in this most rigorous setting, where the relationship between digitalization and delegation is identified solely through variation in the instruments, we still find evidence that is consistent with our main results.

DISCUSSION

In this research, we examine the relationship between digitalization, i.e., the use of digital tools or systems, and a startup's propensity to make the next step in its life cycle by relying on dedicated managers for decision making. This is an important consideration for startups, as founders need to allocate scarce attention to the various activities in which startups are involved, which may quickly overwhelm the available entrepreneurial attention. Our empirical results indicate that digitalization is positively associated with this first step towards an organizational design in a startup. Digitalization implies that founders will have more information available based on algorithms, sensors or databases that appear in new and potentially complex forms (Sturgeon, 2019) when they make decisions about starting to delegate decision rights. Such digitally enhanced information availability allows founders to make better predictions about

the areas in which delegated decision-making would be most beneficial for the startup and outweighs the costs for a dedicated manager. In line with this reasoning, our results indicate that digitalization accelerates delegation and the speed with which firms can move past the startup phase in their life cycle.

In addition, we test three moderating factors to more precisely identify the information availability mechanism. They exploit the heterogeneity of both founders and startups in the extent to which they will use digital information. Specifically, we find that the effect of digitalization on the delegation of decision-making authority is stronger when founders lack managerial experience. We attribute this finding to the fact that managerial experience would have led founders to recognize the role of organizational design as a tool to alleviate attention overload (Baron *et al.*, 1996; Cooper *et al.*, 1994), even in startups that hardly rely on digitalized operations. In contrast, founders without managerial experience have a comparatively harder time assessing the benefits of delegation. For these individuals, the benefits of delegation become much more visible and salient when digitalization increases the amount of information available.

Moreover, we find that the effect of digitalization to be particularly strong in larger startups. Here, the opportunities from digital data collection are elevated given the volume of data (Sturgeon, 2019). Founders in smaller startups typically have a more accurate view of relevant information even when they are hardly digitalized. In large startup contexts, though, delegation decisions are hard if they are not facilitated by digital data.

Finally, we had argued that the degree of innovativeness in a startup weakens the strength of the relationship between digitalization and the delegation of decision-making authority since innovation activities are inherently risky (Amit *et al.*, 1990) which makes digital information unreliable. Our results support this hypothesis and suggest that digitalization promotes delegation when startups rely on less innovative technologies and known market demands, as much more reliable information becomes available under these conditions leading to earlier delegation.

Our findings make two important contributions to the existing academic literature. First, our study adds to the body of knowledge on the formation of organizational structures in startups (e.g., Foss *et al.*, 2015; Grimpe *et al.*, 2019). This stream of literature has largely focused on startup and founder conditions

for explaining differences in the timing with which dedicated managers emerge in startups (Colombo and Grilli, 2013, provide a review). However, the information environment in which founders have to make these delegation decisions hardly enters extant theory. At the same time, founders report frequently that they waited too long with delegating decision making at the expense of their startup (Grimpe *et al.*, 2019). We offer a first step towards arriving at an increasingly complete theory of how startups begin introducing organizational designs by alleviating strong assumptions about the pool of available information for founders when they make these decisions. We theorize about the availability of information based on the degree of digitalization of a startup because digital tools, such as Slack or GitHub, are hallmarks in many modern startups. Nevertheless, our theoretical logic can be extended to other factors constraining or extending founders' information about the benefits from delegating decision authority. For example, the network connections of founders inside or outside their startup are likely to influence their perception about when to rely on dedicated managers for making decisions.

Second, models based on thresholds in the firm life cycle are key to understanding the essential changes in management as startups evolve into established firms (Gedajlovic *et al.*, 2004; Zahra *et al.*, 2009). Then again, an actionable theory needs to take into account that modern startups rely almost by default on digital tools and how this digital paradigm shift affects their life cycle. At the same time, digitalization research is mostly concerned with the training and education levels of employees to deal with digitalization in firms (e.g., Ritter and Pedersen, 2019) but not its structural consequences for firms and startups. Hence, we shift the theoretical discussion to the organizational design choices that become necessary to reap the benefits of digitalization. We demonstrate its effect for the first step in the professionalization of startup management, i.e., the delegation of decision-making authority by the founders. However, our theoretical reasoning, which is rooted in the digital information availability for organizational design decisions, is likely to apply to a broader set of strategic decisions in startup growth, such as decisions about firm structures or opportunities from outsourcing. Theory that incorporates digitalization into the organizational design choices of firms is useful because it prepares firms, industries, and economies for taking advantage of the economic opportunities of digitalization.

In addition, our research has several implications for startup management. Our findings suggest that startup founders should not only view the information available from digital tools and systems as a way to better understand opportunities and problems, but also to reflect on the organizational design of their startups. In particular, startup founders need to realize that the increased availability of information should go hand in hand with considering the professionalization of management in their startup. Rather than trying to address a multitude of issues on their own, digital information availability can serve as a valuable indicator of when startups need to move on in their life cycle and founders need to delegate. These indicators are otherwise difficult to identify, and digitalization can thus serve as a tool to improve the timing of organizational change in startups. At the same time, our empirical results, together with the insights we gained from the interviews, also provide nuance to the digitalization-delegation relationship, helping founders weigh the benefits and cost of such decisions.

CONCLUSION

Startups provide unique opportunities to study the emergence of organizational designs because the startup phase of firms is usually characterized by flat hierarchies and founders as the ubiquitous decision makers. Eventually, startups need to make the next step in their life cycle because their founders become overloaded. We theorize that the availability of digital information matters at this crucial juncture in a startups' evolution because it enables founders to overcome the inherent uncertainty about whether it is prudent and worthwhile to hand over some decision-making authority to dedicated managers. Hence, we demonstrate that digitalization is not just affecting the products and processes of modern startups but also the emergence of their organizational designs.

In conducting this study, we discover several fruitful avenues for future research. First, we benefit from a large dataset that allows us to track different degrees of digitalization in startups as well as the timing of the delegation of decision-making authority to dedicated managers. We theorize that this relationship stems from the availability of information through digitalization, but we cannot determine how it materializes in startups. Dedicated studies might be able to isolate which digital activities trigger the decision to delegate decision-making authority, and under which conditions managers take over specific activities

in the startup. Such studies would likely benefit from qualitative approaches that can fully capture founders' reasoning.

Second, we rely on entropy balancing to identify the effect of digitalization. While we benefit from a rich set of observable variables to achieve balance, an exogenous source of variation affecting digitalization would be ideal to capture unobservable factors. While our robustness checks using a different measure of digitalization and an instrumental variables approach provide confidence in our results, future studies with specific research designs may be able to provide such consistency tests for our estimates. Third, our study benefits from the opportunity to capture many different types of digitalization across startups. We suspect that the effects vary dynamically, i.e., with the introduction of digital tools and techniques over time. Our current data cannot provide these insights, but future studies can build on our theoretical reasoning and, for example, incorporate experiential learning effects into models explaining startups' organizational design choices. Finally, we theorize about the organizational design choices in increasingly digitalized startups. Future research can build on this foundation and extend our argument to a multi-stage model explaining the performance effects of delegation in digitalized startups.

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TABLES

Table 1. Descriptive statistics

	All firms					Degree of digit. <= Median		Degree of digit. > Median	
	N	Mean	S.D.	Min	Max	N	Mean	N	Mean
Time to delegation of decision-making auth. (in days)	327	453.82	540.03	0.00	2511.00	160	447.04	167	460.32
Degree of digitalization (index)	1438	6.62	3.35	0.00	17.00	757	3.97	681	9.56
Degree of digitalization (index) > Median (y/n)	1438	0.47	0.50	0.00	1.00	757	0.00	681	1.00
Founder has experience as manager (y/n)	1438	0.43	0.49	0.00	1.00	757	0.43	681	0.42
Number of dependent employees	1438	1.70	3.00	0.00	37.25	757	1.87	681	1.51
No. of product innovations before delegation	1438	1.55	0.87	1.00	6.00	757	1.43	681	1.68
Average age of founders	1438	41.65	9.25	17.27	74.68	757	42.46	681	40.74
Number of founders in team	1438	1.60	1.07	1.00	25.00	757	1.51	681	1.70
Founder with tertiary education (y/n)	1438	0.60	0.49	0.00	1.00	757	0.53	681	0.67
Founder has entrepreneurial experience (y/n)	1438	0.53	0.50	0.00	1.00	757	0.46	681	0.61
At least one founder has education in informatics (y/n)	1438	0.09	0.28	0.00	1.00	757	0.03	681	0.15
At least one founder has education in business (y/n)	1438	0.33	0.47	0.00	1.00	757	0.29	681	0.37
No. of patents before delegation	1438	0.27	1.77	0.00	30.00	757	0.28	681	0.26
Firm offers digital products (y/n)	1438	0.25	0.43	0.00	1.00	757	0.09	681	0.43
Employees with tertiary education (y/n)	1438	0.28	0.45	0.00	1.00	757	0.27	681	0.29
Private equity before delegation (y/n)	1438	0.08	0.26	0.00	1.00	757	0.05	681	0.11
High-technology manufacturing	1438	0.16	0.37	0.00	1.00	757	0.16	681	0.17
Technology-intensive services	1438	0.21	0.41	0.00	1.00	757	0.20	681	0.23
Software supply and consultancy	1438	0.09	0.29	0.00	1.00	757	0.03	681	0.16
Conventional manufacturing	1438	0.13	0.33	0.00	1.00	757	0.17	681	0.08
Skill-intensive services	1438	0.10	0.30	0.00	1.00	757	0.08	681	0.11
Business services	1438	0.07	0.26	0.00	1.00	757	0.09	681	0.06
Creative consumer services	1438	0.04	0.19	0.00	1.00	757	0.04	681	0.04
Consumer services	1438	0.04	0.20	0.00	1.00	757	0.05	681	0.04
Construction	1438	0.09	0.28	0.00	1.00	757	0.12	681	0.05
Retail and trade	1438	0.06	0.24	0.00	1.00	757	0.07	681	0.06
Founded 2010	1438	0.12	0.32	0.00	1.00	757	0.14	681	0.09
Founded 2011	1438	0.13	0.33	0.00	1.00	757	0.13	681	0.12
Founded 2012	1438	0.18	0.38	0.00	1.00	757	0.18	681	0.17
Founded 2013	1438	0.20	0.40	0.00	1.00	757	0.19	681	0.21
Founded 2014	1438	0.21	0.41	0.00	1.00	757	0.20	681	0.22
Founded 2015	1438	0.17	0.38	0.00	1.00	757	0.16	681	0.18

Notes: Additional control variable: funding by KfW bank; S.D.: standard deviation; y/n: yes/no.

Table 2. Pairwise correlations of dependent and main explanatory variables (n=1,411)

		VIF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	Time to delegation of decision-making auth. (in days)		1													
(2)	Degree of digitalization (index)	1.41	-0.08*	1												
(3)	Founder has experience as manager (y/n)	1.15	-0.07*	0.03	1											
(4)	Number of dependent employees	1.23	-0.37*	-0.02	0.06*	1										
(5)	No. of product innovations before delegation	1.38	0.17*	0.16*	-0.00	-0.14*	1									
(6)	Average age of founders	1.22	-0.02	-0.09*	0.27*	0.06*	0.01	1								
(7)	Number of founders in team	1.14	-0.02	0.10*	0.14*	0.04	0.05*	-0.02	1							
(8)	Founder with tertiary education (y/n)	1.45	-0.04	0.19*	0.09*	-0.05*	0.10*	0.17*	0.23*	1						
(9)	Founder has entrepreneurial experience (y/n)	1.20	-0.03	0.19*	0.02	-0.02	0.01	0.16*	0.18*	0.24*	1					
(10)	At least one founder has education in informatics (y/n)	1.30	0.02	0.24*	-0.04	-0.06*	0.08*	-0.11*	0.09*	0.14*	0.14*	1				
(11)	At least one founder has education in business (y/n)	1.15	-0.05*	0.11*	0.13*	0.05*	-0.00	0.04	0.13*	0.18*	0.13*	-0.05*	1			
(12)	No. of patents before delegation	1.05	0.03	-0.01	-0.02	-0.02	0.14*	0.07*	0.02	0.09*	0.03	-0.03	-0.01	1		
(13)	Firm offers digital products (y/n)	1.72	-0.02	0.46*	0.00	-0.08*	0.15*	-0.08*	0.11*	0.18*	0.16*	0.38*	0.01	0.00	1	
(14)	Employees with tertiary education (y/n)	1.25	-0.26*	0.06*	0.08*	0.34*	-0.08*	0.10*	0.09*	0.20*	0.10*	0.03	0.04	0.02	0.07*	1
(15)	Private equity before delegation (y/n)	1.11	-0.08*	0.14*	0.03	-0.03	0.04	0.01	0.12*	0.17*	0.06*	0.01	0.01	0.06*	0.12*	0.07*

Notes: * denotes the statistical significance of a pairwise correlation at a 10% level; y/n: yes/no; VIF: variance inflation factor.

Table 3. First stage before and after entropy balancing

Model **Dependent variable: Digitalization larger than median**	**Unbalanced OLS 1st stage** **High digitalization (y/n)** **Coef. (S.E.)**	**Balanced OLS 1st stage** **High digitalization (y/n)** **Coef. (S.E.)**
Founder has experience as manager (y/n)	0.002 (0.026)	-0.000 (0.039)
Number of dependent employees	-0.001 (0.004)	0.003 (0.007)
No. of product innovations before delegation	0.072 (0.016)***	0.036 (0.024)
Average age of founders	-0.005 (0.001)***	0.000 (0.002)
Number of founders in team	0.005 (0.012)	0.001 (0.018)
Founder with tertiary education (y/n)	0.017 (0.030)	0.014 (0.044)
Founder has entrepreneurial experience (y/n)	0.071 (0.026)***	-0.004 (0.038)
At least one founder has education in informatics (y/n)	0.087 (0.041)**	-0.013 (0.077)
At least one founder has education in business (y/n)	0.060 (0.028)**	-0.011 (0.041)
No. of patents before delegation	-0.006 (0.008)	-0.014 (0.009)
Firm offers digital products (y/n)	0.341 (0.033)***	-0.016 (0.046)
Employees with tertiary education (y/n)	-0.019 (0.030)	-0.034 (0.044)
Private equity before delegation (y/n)	0.101 (0.044)**	0.005 (0.069)
Industry fixed effects	Yes	Yes
Year of foundation fixed effects	Yes	Yes
Constant	Yes	Yes
N	1438 / 0.202	1438 / 0.02

Notes: Significance levels: *** 1%, ** 5%, * 10%. Robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank.

Table 4. Main results: Coefficients from Cox proportional-hazard models

Model **Dependent variable: Delegation of decision-making authority**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**
Degree of digitalization (index)	0.077 (0.023)***	0.122 (0.030)***	0.055 (0.025)**	0.178 (0.042)***	0.188 (0.047)***
Founder has experience as manager (y/n)	0.160 (0.148)	0.811 (0.347)**	0.144 (0.149)	0.166 (0.147)	0.790 (0.351)**
Number of dependent employees	0.105 (0.017)***	0.105 (0.017)***	0.057 (0.033)*	0.106 (0.017)***	0.064 (0.034)*
No. of product innovations before delegation	-0.629 (0.111)***	-0.626 (0.110)***	-0.627 (0.111)***	-0.122 (0.220)	-0.183 (0.225)
Degree of digit. (index) * Founder has experience as manager		-0.087 (0.038)**			-0.086 (0.039)**
Degree of digit. (index) * Number of dependent employees			0.009 (0.005)*		0.008 (0.005)*
Degree of digit. (index) * No. of product innov. before delegation				-0.070 (0.026)***	-0.061 (0.027)**
Average age of founders	-0.003 (0.008)	-0.002 (0.008)	-0.004 (0.008)	-0.003 (0.008)	-0.003 (0.008)
Number of founders in team	-0.035 (0.085)	-0.032 (0.087)	-0.026 (0.082)	-0.039 (0.087)	-0.028 (0.086)
Founder with tertiary education (y/n)	0.151 (0.175)	0.141 (0.176)	0.118 (0.177)	0.124 (0.173)	0.089 (0.176)
Founder has entrepreneurial experience (y/n)	0.160 (0.159)	0.149 (0.158)	0.161 (0.159)	0.162 (0.159)	0.151 (0.158)
At least one founder has education in informatics (y/n)	-0.291 (0.237)	-0.331 (0.236)	-0.302 (0.240)	-0.316 (0.237)	-0.371 (0.241)
At least one founder has education in business (y/n)	0.056 (0.155)	0.090 (0.155)	0.045 (0.155)	0.080 (0.156)	0.099 (0.156)
No. of patents before delegation	-0.039 (0.040)	-0.037 (0.040)	-0.040 (0.040)	-0.046 (0.042)	-0.043 (0.042)
Firm offers digital products (y/n)	0.252 (0.201)	0.266 (0.201)	0.264 (0.202)	0.271 (0.203)	0.294 (0.203)
Employees with tertiary education (y/n)	1.007 (0.160)***	1.010 (0.160)***	0.987 (0.160)***	1.030 (0.157)***	1.005 (0.157)***
Private equity before delegation (y/n)	0.389 (0.214)*	0.369 (0.214)*	0.384 (0.215)*	0.382 (0.216)*	0.356 (0.218)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year of foundation fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
N	1438	1438	1438	1438	1438

Notes: Coefficients from weighted Cox regression. Weights retrieved by entropy balancing. Significance levels: *** 1%, ** 5%, * 10%. Robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank.

APPENDICES

Appendix A: Tables

Table 5. Details on measures

Variable	Construction
Time to delegation of decision-making authority	Time between startup foundation and the first delegation of decision-making authority in days.
Degree of digit. (index)	Index counting the number of used digital tools in the respective survey questions.
Founder has experience as manager	Dummy variable – Takes a value of one if the founder (or at least one founder in the team) held a position with at least middle management responsibilities in prior employment.
Number of dependent employees	Full-time equivalent number of reportable employees subject to social security contributions. This includes regular full-time and part-time employees, apprentices, interns, and marginally employed personnel.
No. of product innovations before delegation	Number of years before the first of delegation of decision-making authority in which the firm reported any new or significantly improved products.
Average age of founders	Average age of the founders.
Number of founders in team	Number of founders (in the founding team) according to the survey data.
Founder with tertiary education	Dummy variable – Takes a value of one if the founder (or at least one founder in the team) has a tertiary degree.
Founder has entrepreneurial experience	Dummy variable – Takes a value of one if the founder (or at least one founder in the team) started up own company before or was self-employed prior to starting the firm.
At least one founder has education in informatics	Dummy variable - At least one founder with education in informatics.
At least one founder has education in business	Dummy variable - At least one founder with education in business administration.
No. of patents before delegation	Number of patents a founder self-reported to hold before the first delegation of decision-making authority.
Firm offers digital products	Dummy variable – Takes a value of one if the firm offers any digital products.
Employees with tertiary education	Dummy variable – Takes a value of one if at least one dependent employees has a tertiary degree.
Private equity before delegation	Dummy variable – Takes a value of one if a firm reported any equity investors before the first delegation of decision-making authority.

Appendix B: Supplementary material

Table 6. Entropy balancing outcomes

	Treatment group			Control group		
	Before weighting					
	Mean	Variance	Skewness	Mean	Variance	Skewness
Average age of founders	40.74	84.68	0.22	42.46	85.09	0.02
Founder has experience as manager (y/n)	0.42	0.24	0.31	0.43	0.25	0.28
Founder has entrepreneurial experience (y/n)	0.61	0.24	-0.45	0.46	0.25	0.18
At least one founder has education in informatics (y/n)	0.15	0.13	1.95	0.03	0.03	5.23
At least one founder has education in business (y/n)	0.37	0.23	0.55	0.29	0.21	0.94
Firm offers digital products (y/n)	0.43	0.25	0.29	0.09	0.08	2.81
No. of product innovations before delegation	1.68	0.85	1.59	1.43	0.66	2.38
Private equity before delegation (y/n)	0.11	0.09	2.56	0.05	0.05	4.19
High-technology manufacturing	0.17	0.14	1.74	0.16	0.13	1.87
Technology-intensive services and software	0.39	0.24	0.45	0.23	0.18	1.28
Conventional manufacturing	0.08	0.07	3.11	0.17	0.14	1.78
Construction	0.05	0.05	3.93	0.12	0.11	2.34
	After weighting					
	Mean	Variance	Skewness	Mean	Variance	Skewness
Average age of founders	40.74	84.68	0.22	40.74	84.69	0.22
Founder has experience as manager (y/n)	0.42	0.24	0.31	0.42	0.24	0.31
Founder has entrepreneurial experience (y/n)	0.61	0.24	-0.45	0.61	0.24	-0.45
At least one founder has education in informatics (y/n)	0.15	0.13	1.95	0.15	0.13	1.95
At least one founder has education in business (y/n)	0.37	0.23	0.55	0.37	0.23	0.55
Firm offers digital products (y/n)	0.43	0.25	0.29	0.43	0.25	0.29
No. of product innovations before delegation	1.68	0.85	1.59	1.68	0.85	1.59
Private equity before delegation (y/n)	0.11	0.09	2.56	0.11	0.09	2.57
High-technology manufacturing	0.17	0.14	1.74	0.17	0.14	1.74
Technology-intensive services and software	0.39	0.24	0.45	0.39	0.24	0.46
Conventional manufacturing	0.08	0.07	3.11	0.08	0.07	3.11
Construction	0.05	0.05	3.93	0.05	0.05	3.93

Table 7. Robustness checks: Coefficients from Cox proportional-hazard and linear models

Model **Dependent variable: Delegation of decision-making auth.**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Unbalanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Unbalanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced OLS Time to deleg. Coef. (S.E.)**
Degree of digitalization (index) > Median (y/n)	0.322 (0.152)**		0.354 (0.131)***		
Degree of digitalization (index)		0.191 (0.078)**		0.084 (0.019)***	-54.664 (17.756)***
Degree of digitalization (index) squared		-0.007 (0.005)			
Founder has experience as manager (y/n)	0.188 (0.149)	0.167 (0.149)	0.239 (0.121)**	0.209 (0.122)*	-146.245 (113.864)
Number of dependent employees	0.106 (0.017)***	0.105 (0.017)***	0.092 (0.015)***	0.090 (0.015)***	-205.087 (32.085)***
No. of product innovations before delegation	-0.602 (0.108)***	-0.625 (0.110)***	-0.571 (0.093)***	-0.607 (0.097)***	342.354 (58.619)***
Average age of founders	-0.003 (0.008)	-0.003 (0.008)	-0.005 (0.006)	-0.004 (0.007)	5.398 (6.525)
Number of founders in team	-0.041 (0.088)	-0.036 (0.087)	-0.112 (0.072)	-0.106 (0.071)	-5.000 (67.821)
Founder with tertiary education (y/n)	0.170 (0.177)	0.128 (0.178)	0.204 (0.142)	0.187 (0.140)	-109.755 (124.626)
Founder has entrepreneurial experience (y/n)	0.176 (0.160)	0.164 (0.160)	0.090 (0.125)	0.067 (0.125)	-54.009 (122.577)
At least one founder has education in informatics (y/n)	-0.326 (0.235)	-0.300 (0.240)	-0.176 (0.214)	-0.141 (0.213)	50.736 (209.951)
At least one founder has education in business (y/n)	0.072 (0.155)	0.062 (0.156)	0.225 (0.128)*	0.200 (0.127)	3.865 (117.783)
No. of patents before delegation	-0.034 (0.037)	-0.038 (0.040)	-0.105 (0.055)*	-0.121 (0.059)**	12.173 (17.811)
Firm offers digital products (y/n)	0.322 (0.197)	0.252 (0.200)	0.183 (0.164)	0.091 (0.165)	-201.080 (160.238)
Employees with tertiary education (y/n)	0.990 (0.159)***	0.995 (0.159)***	0.861 (0.127)***	0.876 (0.127)***	-718.511 (161.256)***
Private equity before delegation (y/n)	0.414 (0.217)*	0.400 (0.215)*	0.311 (0.193)	0.270 (0.191)	-505.290 (231.163)**
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year of foundation fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
N	1438	1438	1438	1438	1438 / 0.244

Notes: Coefficients from weighted regressions. Weights retrieved by entropy balancing. Significance levels: * 1%, ** 5%, * 10%. Robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank.**

Table 8. Additional specifications: Coefficients from Cox proportional-hazard models

Model **Dependent variable: Delegation of decision-making authority**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**
Degree of digit. (index) (connectivity)	0.177 (0.046)***	0.212 (0.064)***	0.132 (0.052)**	0.344 (0.094)***	0.317 (0.110)***
Founder has experience as manager (y/n)	0.124 (0.150)	0.323 (0.321)	0.126 (0.151)	0.131 (0.150)	0.364 (0.321)
Number of dependent employees	0.110 (0.016)***	0.110 (0.016)***	0.074 (0.027)***	0.111 (0.016)***	0.078 (0.027)***
No. of product innovations before delegation	-0.653 (0.113)***	-0.652 (0.113)***	-0.647 (0.113)***	-0.338 (0.199)*	-0.384 (0.203)*
Degree of digit. (index) (connectivity) * Founder has experience as middle manager (y/n)		-0.069 (0.086)			-0.082 (0.087)
Degree of digit. (index) (connectivity) * Number of dependent employees			0.017 (0.009)**		0.016 (0.009)*
Degree of digit. (index) (connectivity) * No. of product innovations before delegation				-0.117 (0.058)**	-0.098 (0.059)*
Average age of founders	-0.002 (0.008)	-0.002 (0.008)	-0.003 (0.008)	-0.002 (0.008)	-0.002 (0.008)
Number of founders in team	-0.096 (0.088)	-0.095 (0.088)	-0.073 (0.084)	-0.091 (0.088)	-0.072 (0.084)
Founder with tertiary education (y/n)	0.263 (0.158)*	0.255 (0.159)	0.240 (0.159)	0.239 (0.156)	0.212 (0.159)
Founder has entrepreneurial experience (y/n)	0.122 (0.154)	0.123 (0.154)	0.144 (0.155)	0.126 (0.154)	0.144 (0.154)
At least one founder has education in informatics (y/n)	-0.192 (0.224)	-0.203 (0.228)	-0.206 (0.224)	-0.189 (0.222)	-0.218 (0.229)
At least one founder has education in business (y/n)	0.085 (0.143)	0.095 (0.143)	0.058 (0.144)	0.097 (0.143)	0.083 (0.143)
No. of patents before delegation	-0.064 (0.050)	-0.062 (0.050)	-0.069 (0.051)	-0.067 (0.050)	-0.067 (0.051)
Firm offers digital products (y/n)	0.292 (0.190)	0.292 (0.190)	0.292 (0.190)	0.296 (0.190)	0.296 (0.190)
Employees with tertiary education (y/n)	0.806 (0.155)***	0.805 (0.155)***	0.776 (0.156)***	0.811 (0.154)***	0.780 (0.154)***
Private equity before delegation (y/n)	0.417 (0.227)*	0.412 (0.226)*	0.411 (0.228)*	0.411 (0.228)*	0.401 (0.228)*
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year of foundation fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
N	1438	1438	1438	1438	1438

Notes: Marginal effects from weighted cox regressions. Weights retrieved by entropy balancing. Significance levels: *** 1%, ** 5%, * 10%. (Cluster)-robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank.

Table 9. Additional specifications: Coefficients from Cox proportional-hazard models

Model **Dependent variable: delegation of decision-making authority**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**	**Balanced Cox Hazard (Deleg.) Coef. (S.E.)**
Degree of digit. (index) (coordination)	0.089 (0.033)***	0.165 (0.044)***	0.063 (0.036)*	0.203 (0.066)***	0.237 (0.071)***
Founder has experience as manager (y/n)	0.100 (0.141)	0.788 (0.331)**	0.077 (0.143)	0.101 (0.141)	0.769 (0.333)**
Number of dependent employees	0.105 (0.018)***	0.107 (0.018)***	0.068 (0.033)**	0.106 (0.018)***	0.072 (0.033)**
No. of product innovations before delegation	-0.602 (0.109)***	-0.600 (0.109)***	-0.604 (0.109)***	-0.223 (0.215)	-0.275 (0.224)
Degree of digit. (index) (coordination) * Founder has experience as middle manager (y/n)		-0.142 (0.059)**			-0.143 (0.060)**
Degree of digit. (index) (coordination) * Number of dependent employees			0.009 (0.007)		0.009 (0.007)
Degree of digit. (index) (coordination) * No. of product innovations before delegation				-0.081 (0.041)*	-0.069 (0.043)
Average age of founders	0.001 (0.008)	0.001 (0.008)	0.001 (0.008)	0.001 (0.008)	0.001 (0.008)
Number of founders in team	-0.002 (0.073)	-0.001 (0.076)	0.000 (0.072)	-0.007 (0.076)	-0.002 (0.077)
Founder with tertiary education (y/n)	0.152 (0.176)	0.142 (0.176)	0.123 (0.178)	0.135 (0.175)	0.101 (0.177)
Founder has entrepreneurial experience (y/n)	0.250 (0.152)*	0.230 (0.152)	0.244 (0.151)	0.251 (0.152)*	0.227 (0.152)
At least one founder has education in informatics (y/n)	-0.217 (0.243)	-0.247 (0.241)	-0.221 (0.245)	-0.235 (0.244)	-0.269 (0.245)
At least one founder has education in business (y/n)	0.074 (0.155)	0.112 (0.154)	0.072 (0.155)	0.093 (0.155)	0.126 (0.155)
No. of patents before delegation	-0.059 (0.046)	-0.058 (0.045)	-0.059 (0.045)	-0.066 (0.049)	-0.063 (0.047)
Firm offers digital products (y/n)	0.245 (0.183)	0.268 (0.183)	0.257 (0.183)	0.264 (0.183)	0.296 (0.183)
Employees with tertiary education (y/n)	1.004 (0.159)***	1.010 (0.160)***	0.997 (0.159)***	1.021 (0.158)***	1.012 (0.159)***
Private equity before delegation (y/n)	0.334 (0.213)	0.312 (0.216)	0.328 (0.214)	0.334 (0.215)	0.305 (0.218)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year of foundation fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes
N	1438	1438	1438	1438	1438

Notes: Marginal effects from weighted cox regressions. Weights retrieved by entropy balancing. Significance levels: *** 1%, ** 5%, * 10%. (Cluster)-robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank.

Table 10. Additional specifications: Longitudinal variation in alternative explanatory variable

Model **Dependent variable: Delegation of decision-making auth.**	**OLS** **Hazard (Delegation)** **Coef. (S.E.)**	**Cox** **Hazard (Delegation)** **Coef. (S.E.)**	**Fixed Effects** **Hazard (Delegation)** **Coef. (S.E.)**	**IV** **Hazard (Delegation)** **Coef. (S.E.)**
Firm employs IT personnel (y/n)	0.024 (0.008)***	0.573 (0.147)***	0.021 (0.012)*	0.067 (0.025)***
Founder has experience as manager (y/n)	0.005 (0.002)**	0.277 (0.094)***		0.005 (0.002)**
Number of dependent employees	0.012 (0.001)***	0.123 (0.009)***	0.020 (0.002)***	0.011 (0.001)***
No. of product innovations before delegation	-0.006 (0.001)***	-0.257 (0.041)***		-0.006 (0.001)***
Average age of founders	-0.000 (0.000)***	-0.014 (0.005)***		-0.000 (0.000)***
Number of founders in team	0.004 (0.002)**	0.078 (0.034)**		0.004 (0.002)**
Founder with tertiary education (y/n)	0.002 (0.002)	0.099 (0.098)		0.002 (0.002)
Founder has entrepreneurial experience (y/n)	0.004 (0.002)**	0.340 (0.093)***		0.003 (0.002)*
At least one founder has education in informatics (y/n)	0.003 (0.003)	-0.003 (0.169)		0.001 (0.003)
At least one founder has education in business (y/n)	0.003 (0.002)*	0.130 (0.102)		0.003 (0.002)*
No. of patents before delegation	0.000 (0.000)	0.002 (0.008)		0.000 (0.000)
Employees with tertiary education (y/n)	0.036 (0.006)***	1.336 (0.109)***	0.030 (0.008)***	0.029 (0.006)***
Private equity before delegation (y/n)	0.010 (0.006)*	0.313 (0.172)*		0.009 (0.006)*
Industry fixed effects	Yes	Yes	Yes	Yes
Year of foundation fixed effects	Yes	Yes	Yes	Yes
Analysis time fixed effects	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
N / R-sq.	35634 / 0.083	35634	35634 / 0.084	35634 / 0.08

Notes: Significance levels: *** 1%, ** 5%, * 10%. (Cluster)-robust standard errors in parentheses. Additional control variables in all regressions: Funding by KfW bank