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Article

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MANAGEMENT | RESEARCH ARTICLE

The significance of technology-driven entrepreneurship activities: Lessons from SMEs operating in the manufacturing industry

Anil Yigit^{1*} and Dominik K. Kanbach²

Abstract: Innovation in small and medium enterprises (SMEs) is often the result of technology-driven or market-pull entrepreneurship activities. So far, although its importance in practice, as well as in academia continues to grow, extant research exhibits little theory about the process of technology-driven entrepreneurship in SMEs. The study aims to better understand how technology-driven entrepreneurship processes transform business in SMEs in the manufacturing industry. Therefore, we developed a technological entrepreneurship (TE) process framework by utilizing the flexible pattern matching approach (FPMA). We iteratively compared a priori patterns from existing theoretical knowledge to empirical findings that emerged from in-depth interviews with corporate executives in the manufacturing industry. The framework highlights the TE process in SMEs leading to four output components: (1) corporate-function-related, (2) business-model-related, (3) competitiveness-related, and (4) customer-related. This study makes a unique contribution to academia by being the first that develops a TE process framework tailored to SMEs from the manufacturing industry. We point out that sustainable growth and competitiveness of SMEs depends on appropriate TE process management, and we underline the strategic importance of TE-driven transformation for SME managers. Our study expands the scope of TE and SME research and provides empirically grounded insights into technology-driven innovation.

Subjects: Management of Technology & Innovation; Entrepreneurship; Small Business Management

Keywords: Technology-driven entrepreneurship; technological entrepreneurship; small and medium enterprises; flexible pattern matching approach; innovation

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1. Introduction

The number of academic studies that consider the subject of either Technological Entrepreneurship (TE) or Small and Medium Enterprises (SMEs) has increased significantly in the management literature (Majdouline et al., 2022). More than 60 percent of the literature related to the topic of TE or SMEs has appeared in the last 10 years. According to numerous studies, TE activities especially encompass great potential for innovation, economic growth, and competitive advantage for SMEs (Bailetti, 2012; Hitt et al., 2001; Petti, 2009). Despite the immensely increasing importance of this topic, limited research examines various facets of TE and its significance for SMEs. According to Prodan (2011), TE has a high relevance for SMEs, and technology-driven activities can be successfully carried out in SMEs, particularly if they collaborate with innovative organizations such as new technology-based institutes or research centers. Prodan (2011) further emphasizes that governments need to expedite technology-driven development in SMEs. In another study, Cavallo et al. (2021) highlight that the role of SMEs in regard to innovative entrepreneurial activities remains under-researched and requires further examination. Both studies underline the need for further research in the field of TE in SMEs. To understand the specific research gaps in this field more precisely and to focus on them in a systematic way, we started by developing an understanding of the current state of research on this topic.

To date, scholarly research has dealt with the general definition of TE activities and related processes (Bailetti, 2012; Chaston, 2017; Majdouline et al., 2022; Passiante & Romano, 2016; Petti, 2009). Numerous examples of unexplored issues exist, such as how SMEs can transform their business through utilizing TE activities and what the main drivers and benefits are of TE in SMEs. Another unaddressed aspect is the need to comprehend what process, including relevant components, underlies TE activities in SMEs and why the theoretical framework of implementing TE in SMEs differs from any other type of company (Cavallo et al., 2021; Petti, 2009; Prodan, 2011). Moreover, Liu et al. (2022) clarify that previous studies on TE have largely focused on technology-driven companies operating in the North American manufacturing industry. Muldoon et al. (2022) emphasize that geographical characteristics play an important role within entrepreneurial ecosystem and are critical to the economic development as well as technological innovation of firms. However, a geographic region is strongly determined by various factors such as politics, culture, or human capital (Isenberg, 2010). The expression of these factors can vary greatly from region to region, potentially leading to different outcomes with respect to TE initiatives. In this context, it is crucial to understand the extent to which previous findings on TE activities apply to further geographic regions.

In this paper, we investigate the existing research gap in greater detail and aim to answer the research question of how technology-driven entrepreneurship processes transform the business of SMEs operating in the German manufacturing industry as a representative example from the Central European area. To do so, we employ the flexible pattern matching approach (FPMA) and develop our TE process framework for SMEs by iteratively comparing theory from extant research to empirical data (Bouncken et al., 2021a, 2021b).

Our paper consists of six sections. First, we provide background on current literature about TE and develop the theoretical patterns relevant to the initial flexible pattern matching template. In the second section, we demonstrate our research methodology and provide further insights regarding the applied research design, characteristics of the selected sample, approach to data collection, and the final data structure resulting from the data analysis. The third part matches the research findings emerging from the theoretical patterns and empirical findings arising out of in-depth interviews with corporate executives in the manufacturing industry. In the fourth section, we critically discuss the results from the FPMA and summarize our theoretical contributions. The fifth section of the work concludes with our main findings and their managerial implications. In the final section, we present the limitations of this study and suggestions for future research.

2. Background on literature and development of theoretical patterns

In this section, we provide an overview of the current status of academic contributions regarding TE activities. Based on our literature review, we identify key areas for further research and define the scope of this study. Following the FPMA, we develop an initial flexible pattern matching template that we base on theoretical patterns resulting from an analysis of extant literature, to guide us through the entire analysis process (Bouncken et al., 2021a, 2021b; Sinkovics et al., 2021). In the findings section of this paper, we then extend the initial flexible pattern matching template, with the help of our empirical observations, and develop the final TE process framework especially tailored to SMEs operating in the manufacturing industry.

2.1. Technological entrepreneurship

2.1.1. Definitions and literature review

The literature shows several synonyms for TE, such as technological entrepreneurship, technology entrepreneurship, technology-driven entrepreneurship, technical entrepreneurship, or techno-entrepreneurship. In our study, we mainly refer to “technological” or “technology-driven” entrepreneurship (TE). To understand the characteristics of TE to a greater extent, we defined TE by separately focusing on its two components, technology and entrepreneurship (Petti, 2009). “Technology” summarizes all skills, artifacts, and theoretical and practical knowledge for developing and producing products and services (Burgelman et al., 2004). Entrepreneurship is the establishment of new or the composition of existing resources in a different way to identify and exploit heretofore uncharted market opportunities (Hitt et al., 2001). Entrepreneurial activities are beneficial to entering new markets, developing and launching new products, or providing valuable services to new customers (Hitt et al., 2001; Ireland et al., 2001; Kuratko et al., 2001; Sexton & Smilor, 1997).

Not considering TE as an outcome that solely relates to the exceptional ideas of individuals is crucial. Rather, TE is a process whose outcome results from technology-related activities by different individuals and groups within a suitable environment for entrepreneurial activities (Petti, 2009). Bailetti (2012) defines TE as an investment in a project to create and capture value for a firm, by bringing together particular individuals and heterogeneous assets closely affiliated to progress in scientific and technological knowledge.

Thus far, numerous studies have dealt with the topic of TE and its corresponding process components. In Table 1, we summarize the most important findings from our literature review about TE and refer to the aspects that are not yet covered in detail in the existing literature. These aspects are considered as points of reference for our study.

2.1.2. Main areas for further research and strategic importance of TE for SMEs

The analysis of existing literature gave us important stimuli for possible further fields of research. The main opportunities for further research resulting from the literature review are as follows:

- The TE process and its underlying components have not yet been analyzed in detail with a specific focus on SMEs.
- The previous geographical focus of TE research was mainly on North America. New findings from other regions would enrich this research area.
- The manufacturing industry plays an important role in TE activities and should therefore be analyzed more specifically.

Globally, most firms can be classified as SMEs, representing approximately 90 percent of businesses, and thus making a significant contribution to the global economy (Sabando-Vera et al., 2022). Although the potential is estimated to be considerably greater, only a small portion of SMEs stand out due to innovation and TE activities leading to competitive advantages (Pashley et al., 2020; Staniewski et al., 2016). The successful implementation of TE activities in SMEs holds

Table 1. Main findings from literature review

Study	Relevant Findings	Potential Points of Reference for this Study
Hitt et al. (2001)	Authors emphasize that smaller firms develop many entrepreneurial, breakthrough technologies. Further, they indicate that smaller firms are more open to new ways of learning and working when experimenting with new technologies.	Examining further details regarding the reason why small businesses are particularly well suited for developing these technologies and how the underlying TE process is structured.
Garud and Karnøe (2003)	Authors refer to TE, highlighting the distributed nature of agency. They underline that manufacturing (production) is one of the main involved actors in developing a technology.	Analyzing the implementation of new technologies in the manufacturing industry. Creating a reference to the importance of company size for TE activities in manufacturing firms.
Venkataraman (2004)	Author examines the role of TE in regional transformation with a particular focus on the United States. Further, seven intangibles of regional TE are highlighted that are important to foster TE.	Expanding the focus to further regions beyond the United States of America (USA). Considering the significance of company size and structure in connection with the results of the study.
Petti (2009)	Author provides a systematic understanding of TE and the underlying TE process which connects the development of technology with the creation of business. It generally refers to the role of TE in SMEs and the resulting innovation potentials.	Building an even deeper reference for the role of company size and regional circumstances when implementing TE activities in SMEs.
Prodan (2011)	Author provides a TE model comprising seven levels of key TE elements. It is underlined that SMEs are required to collaborate with innovative organizations (e.g., universities) to carry out TE activities successfully. Further, the author underlines that governments need to expedite technology-driven developments in SMEs.	Linking the findings of the study more concretely to SMEs operating in a specific industry. Building comprehension of the reasons why SMEs need to collaborate with innovative organizations when initiating TE activities. Understanding the role of government when implementing TE activities.
Siyanbola et al. (2011)	Authors develop a framework for setting up TE in developing countries. They highlight that there is almost no focus on TE activities in developing countries.	Building a reference to the applicability of this framework in SMEs from a specific industry.
Bailetti (2012)	Author provides a definition of TE and an overview of main themes related to TE. The author points out the significance of TE for leaders and top managers in SMEs targeting to create, deliver, and capture value to their stakeholders through technology.	Creating an in-depth understanding regarding why the main TE themes are relevant to SMEs. Examining the strategic importance of TE for SME managers in more detail.
Habtay (2012)	Author analyzes the differences in technology-driven and market-driven innovations with regard to their relative disruptiveness potential. A framework for disruptive business model innovation development is provided.	Setting up a particular focus on the role of company size, structure, and the underlying TE process.

(Continued)

Study	Relevant Findings	Potential Points of Reference for this Study
Passiante and Romano (2016)	Authors provide a definition of TE and guidelines for the framework of entrepreneurial learning. Further, the authors add that TE attitudes in SMEs particularly need to be supported and developed by prioritizing them on political agendas.	Building a concrete reference for the extent of applicability of TE guidelines in SMEs. Examining the concrete role of politics in TE activities in SMEs.
Chaston (2017)	Author provides insights into new concepts concerning the utilization and management of TE and its corresponding process components.	Creating a reference for the role of company size and importance of regional circumstances.
Maysami et al. (2019)	Authors introduce a TE ecosystem including its key components. Additionally, they provide a framework for the measurement of this ecosystem.	Relating the TE definition, components of the TE ecosystem, and further insights of the study to SMEs in particular.
Cavallo et al. (2021)	Authors accentuate the need for further examination of the collaboration between SMEs and innovative startups when carrying out TE activities.	Providing further detail on why the collaboration between SMEs and innovative startups is important when conducting TE activities.
Al-Shami et al. (2022)	Authors highlight the importance of an entrepreneurial orientation to the innovation performance of SMEs.	Making a more specific reference for how a TE orientation increases innovation performance in SMEs.
Liu et al. (2022)	Authors emphasize that effective management of TE is important for the competitive advantages and performances of firms operating in the manufacturing industry. They further state that extant research on TE predominantly focuses on the geographical region of North America.	Focusing on firms that are operating in the manufacturing industry outside the USA. Creating an understanding of how the effective management of TE ensures the competitive advantage and performance of SMEs.
Majdouline et al. (2022)	Authors provide a systematic literature review of the current status of research on TE and group the TE evolution into three main stages.	Examining in detail how the TE process and its components can be applied in a particular industry, type of firm, or geographical region.

great growth potentials, making a more detailed analysis of this phenomenon in SMEs indispensable.

Many studies have examined the phenomenon of the German Mittelstand, particularly highlighting the economic stability and crisis-resistance of German SMEs. Unlike most countries, SMEs represent the backbone of the German economy and stand out due to their technological strength (Berlemann et al., 2022; Pahnke & Welter, 2019; Röhl & Engels, 2021), making it even more crucial and interesting to analyze TE activities in the German SME sector.

Furthermore, manufacturing plays a central role in developing a new technology (Garud & Karnøe, 2003). Initial studies are focusing on the analysis of TE activities in the manufacturing industry with a specific geographical focus on North America and China for this reason (Liu et al., 2022).

In addition, the literature review highlighted that TE is a type of business leadership (Prodan, 2011) and particularly addressed executives and top managers in SMEs who are aiming to create, capture, and deliver value to their customers through technology (Bailetti, 2012). SME managers need to understand the immense opportunities associated with conducting TE activities in SMEs. They must ensure the availability of essential resources and capabilities required for the successful utilization of TE in SMEs.

To analyze these research areas in more detail and make a crucial academic contribution, this study focuses on the significance of TE for SMEs operating in the German manufacturing industry.

2.1.3. Theoretical components of the TE process

After identifying potential areas for further research and scientifically deriving the research focus of this paper, this section focuses on specifying the main theoretical components of the TE process.

The existing TE definitions indicate that the pursuit of technological advancement can lead to the discovery and formulation of entrepreneurial potential when executing TE activities. Hence, the TE process links progress in technology with the development of new business opportunities, comprising four key activity sets (Petti, 2009):

- Discovering existing technologies or creating new technologies to generate potential business value.
- Recognizing and matching opportunities resulting from the applications of these technologies to meet emerging markets' needs.
- Developing technologies and applications.
- Creating business (value).

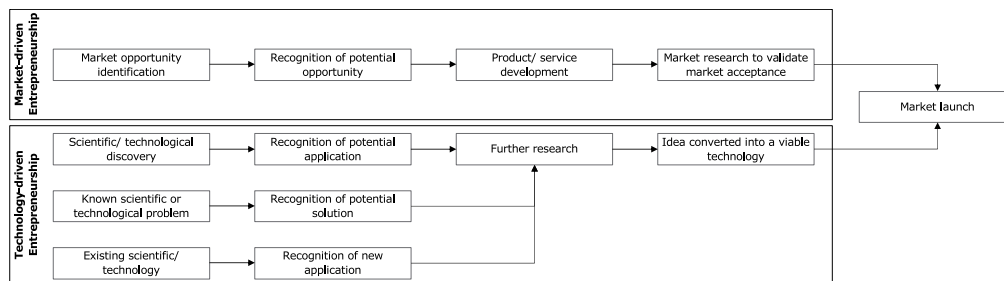
In addition, Petti (2009) highlights the following three key components of TE:

- Entrepreneurial component: Individual and company activities for discovering and utilizing the extraordinary and disruptive potential of rising technologies and business opportunities
- Management component: Activities of individual managers and companies for creating a unique value proposition that enables fast market entry, to accomplish targeted business opportunities based on a proven business model
- Environmental component: Set of formal and informal supporting institutions and resources for designing suitable conditions for technology-based ventures

Habtay (2012) defines the TE process from a slightly different point of view, referring to the differences between market- and technology-driven entrepreneurship. According to Habtay (2012), the basis of both innovation types is a technical process that aims to improve extant or create new business models, products, and services. The term “technology-driven entrepreneurship” is appropriate when a new research-and-development experiment and scientific discovery anticipate market opportunities leading to a feasible business proposition. Conversely, market-driven entrepreneurship exists when the market (the customer) generates demand pressure leading to the discovery of a market innovation before a company invests in a specific product or service (Chaston, 2017). Figure 1 illustrates the characteristics of both technology- and market-driven entrepreneurship.

To cover the most relevant TE-related theoretical aspects in the initial flexible pattern matching template, we likewise considered the main input and output components within the TE ecosystem. Chaston (2017) points out the four core input components in the TE ecosystem: access to scientific and technological advances, technological entrepreneurial capability, technological infrastructure, and interorganizational collaborative environments. The three major output components in this ecosystem are existing market opportunities, new market opportunities, and new-to-the-world opportunities.

Figure 1. Entrepreneurial Process Comparison (based on Chaston, 2017, p. 10).

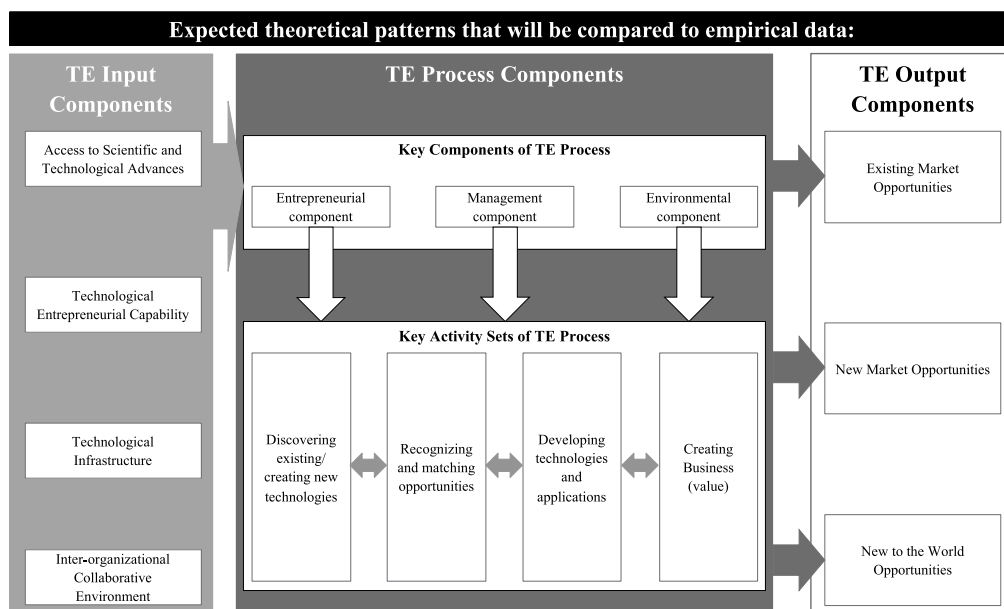


When setting up the TE process, it is also important to be aware of the potential key indicative elements of transformation. To measure the accomplishment level of a transformation generated by TE activities, it is essential to have suitable indicators of innovation performance such as the number of products or services newly launched on the market, the date of the market launch, improvement in cost structure and performances (e.g., in manufacturing processes), or the number of patents applied for (Chaston, 2017; Thamhain, 2003). Furthermore, soft indicators such as the existence of a professionally challenging and stimulating environment or a suitable composition of the involved team members leading to effective communications within the team, are also fundamental metrics that must be considered as soft indicative elements of a TE transformation (Thamhain, 2003).

2.2. Initial theoretical flexible pattern matching template

Considering the most relevant aspects regarding the definition and understanding of TE, we developed the initial theoretical flexible pattern matching template (Figure 2). This initial conceptual model represents a general illustration of a priori patterns from existing theoretical knowledge on this research topic (Bouncken et al., 2021b). This template also guided us through the entire data collection and analysis process for the empirical data.

Figure 2. Initial theoretical flexible pattern matching template (own illustration based on Petti, 2009; Chaston, 2017).



3. Research methodology

3.1. Research design

Qualitative research methods support the development of new theories and contribute valuable insights, particularly in situations where changes in companies, for example, due to technological advancements, need to be investigated (Bouncken et al., 2021a). For the development of new theory and building a framework for the TE process, particularly in SMEs, we considered the FPMA, which stepwise compares previous theory from existing academic research to patterns resulting from empirical data (Bouncken et al., 2021a, 2021b; Sinkovics, 2018). Exploratory research that examines new technological developments and innovations especially uses the FPMA logic for integrating deduction and induction analysis (Bouncken et al., 2021a). Likewise, the generalizability of the research results and the evolved theory increases significantly by bridging extant theory with collected empirical data (Bouncken et al., 2021b). As Bouncken et al. (2021b) suggest, we considered the key stages and roadmap of the FPMA, which Figure 3 illustrates.

Furthermore, an important link exists between the FPMA and grounded-theory approach, methods that are not mutually exclusive. The FPMA enables researchers to deeply analyze empirical observations using the Gioia method while simultaneously incorporating existing theory using flexible pattern matching techniques (Bouncken et al., 2021a). Thus, for analyzing our empirically collected data, we considered the grounded-theory approach of Gioia et al. (2013) and then integrated the empirical findings into the FPMA to develop a fully comprehensive theory (Bouncken et al., 2021a, 2021b).

3.2. Sample and data collection

Within the scope of this paper, we used purposive and theoretical sampling to collect empirical data. To ensure that we focus on the relevant group of respondents and they make a significant contribution to our study, purposive sampling was applied based on certain criteria, which are described below. For gathering in-depth insights, we subsequently considered the method of theoretical sampling (Ghorbani et al., 2023; Lichtenstein & Williamson, 2006). Theoretical sampling is a very well-known method when considering the grounded theory approach for analyzing qualitative data (Gioia et al., 2013; Glaser & Strauss, 1967). This involves searching for additional data based on concepts derived from the initial analysis. Thus, the evolving theory can be further extended and refined until theoretical saturation is achieved (Ligita et al., 2020).

Based on the derived findings in the theory section of this paper, we examine the significance of TE activities for SMEs operating in the German manufacturing industry. As underlined in the previous section, the special characteristics and structures of the German Mittelstand offer the opportunity to gather completely new and unique insights. Therefore, our sample consisted of interviewees working in SMEs that met certain requirements. First, the selected interviewees and SMEs must have had substantial experience in implementing and executing TE activities leading to significant innovations and transformations in their businesses. Second, the sample firms must have operated in Germany's manufacturing industry sector. As an optional third selection criterion, we gave preference to SMEs that were accepted to participate in the Top Innovators Program, comprising Germany's most innovative SMEs (Top 100, 2022). Following the described selection criteria, we conducted 17 in-depth semi-structured

Figure 3. Stages and Roadmap of FPMA (own illustration based on Bouncken et al., 2021b).



Table 2. Overview of Interview Partners (IP)

ID	Role of Interview Partner	Industry	Duration
IP01	Managing Director	Manufacturing Plant Engineering	36 min 46 sec
IP02	Managing Director	Manufacturing Plant Engineering	33 min 18 sec
IP03	Managing Director	Manufacturing Industrial Engineering	30 min 38 sec
IP04	Head of Digital Innovation	Manufacturing Pharmaceuticals	24 min 38 sec
IP05	Managing Director	Manufacturing Construction	27 min 36 sec
IP06	Advisor to the CDO	Manufacturing Mechanical Engineering	39 min 36 sec
IP07	Vice President	Manufacturing Machinery	33 min 45 sec
IP08	Managing Director	Manufacturing Heating	32 min 06 sec
IP09	Innovation Manager	Manufacturing Automation	24 min 12 sec
IP10	Senior Director	Manufacturing Construction	37 min 42 sec
IP11	Head of Customer Excellence	Manufacturing Construction	28 min 04 sec
IP12	Managing Director	Manufacturing Chemicals	26 min 36 sec
IP13	Head of Digitalization	Manufacturing Industrial Engineering	35 min 42 sec
IP14	Director	Manufacturing Heating	25 min 34 sec
IP15	Business Development Manager	Manufacturing Mechanical Engineering	57 min 24 sec
IP16	Reliability Engineering Manager	Manufacturing Industrial Engineering	35 min 48 sec
IP17	Director	Manufacturing Machinery	32 min 52 sec

interviews, each lasting between 24 and 57 minutes, with managers from 13 German SMEs (Table 2). In the treatment of our human sample, we have adhered to APA ethical standards. All interviewees voluntarily participated in the study, were free to withdraw at any time, and gave informed consent for the research. By choosing our interviewees strictly according to the theoretically and scientifically elaborated criteria, our sample fully represents the target population.

According to Glaser and Strauss (1967), theoretical saturation is referred to as the point at which no new variations of the identified concepts can be found in the collected empirical data (Linden & Palmieri, 2021). Furthermore, theoretical saturation is reached when no more new elements can be extracted from the targeted field of observation in order to develop the new theory (Oliveira et al., 2022). Consistent with the definitions from the existing literature, after 17 interviews the field of observation did not provide any additional new elements needed to develop our desired theory. In addition, we found that the constructs of the theory were completely reflected by the collected data, thus reaching the theoretical saturation point as suggested by Glaser and Strauss (1967). Particularly, in our recent empirical observations, we found that the results are largely consistent with the earlier ones. Our empirical data were

Figure 4. Analysis and coding steps.



sufficient to extend the patterns of the initial theoretical FPMA template and develop the final framework. Thus, 17 interviews helped us to attain theoretical saturation such that more interviews would no longer provide additional important new findings (Ahsan et al., 2018; Bouncken et al., 2021b; Eisenhardt, 1989; Locke, 2001).

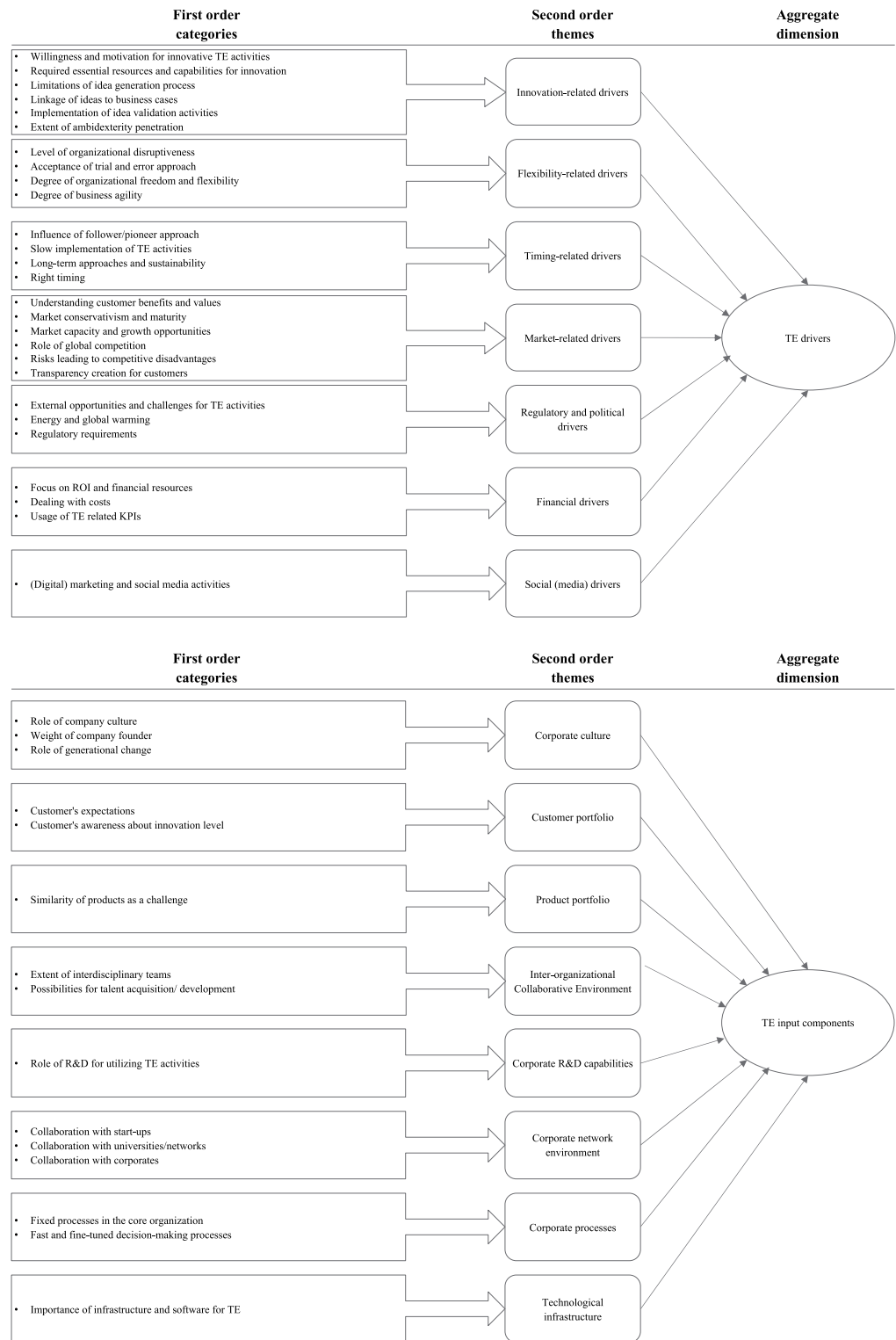
With their basis in a semi-structured interview protocol, all interviews occurred over five months, during which we aimed to gather suitable and detailed examples of TE activities from our sample companies. The interviews occurred in either German or English, and we translated the relevant parts of the German interviews into English. We recorded all interviews and conducted them by video conference or in person. No statement from the interviews is traceable to an individual or a company as we anonymized all interviews. Immediately after the interviews, we transcribed the recordings based on a structured guide (Dresing & Pehl, 2018, 2020).

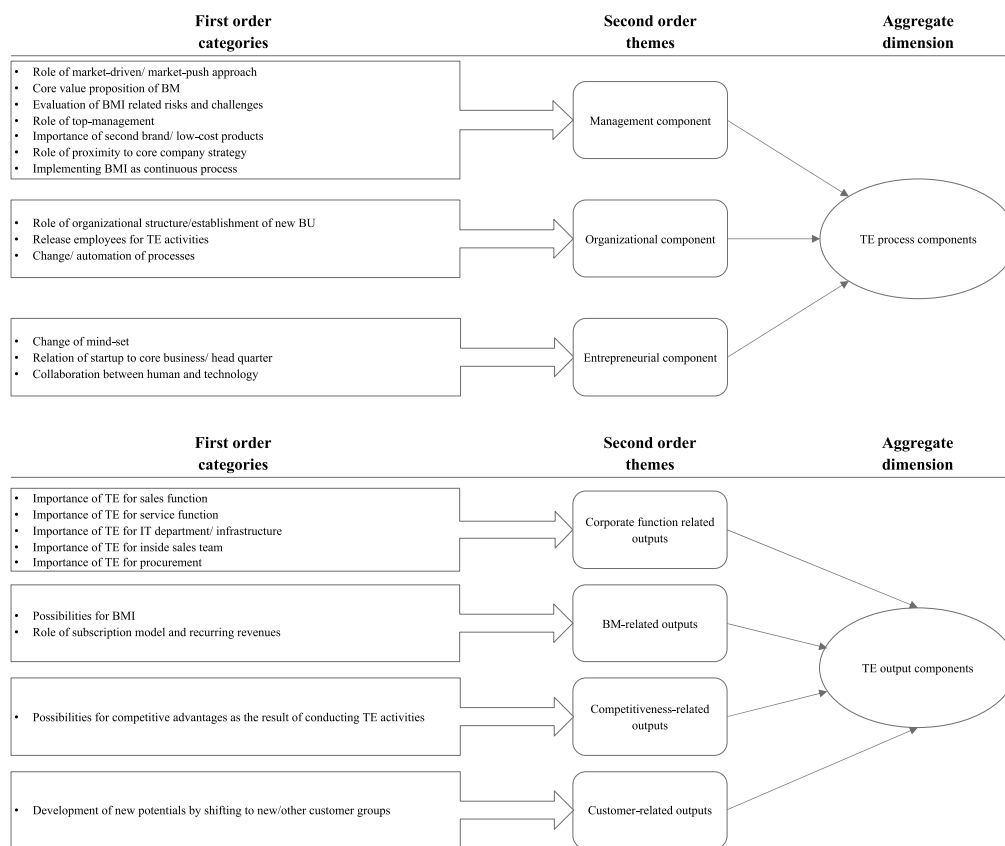
3.3. Data analysis and data structure

Qualitative data gathered from empirical observations can be systematically and flexibly analyzed with the help of qualitative content analysis (Hair et al., 2015; Schreier, 2014). We therefore carried out a qualitative content analysis to systematically answer our research questions. We coded transcribed interviews separately using the Software MAXQDA Analytics Pro (Verbi Software, 2022). To ensure the objectivity of the research and to prevent the individual influence of each researcher, we considered an investigator triangulation (Archibald, 2016; Hair et al., 2015). Thus, the interview data were analyzed and interpreted by both researchers involved in this study. We conducted the content analysis by reading the transcripts multiple times and comparing them with each other by means of a repetitive process. With the help of a systematic inductive approach, the coding and categorization of the transcript material enabled us to identify 539 complementary in vivo codes. The term “in vivo” originates from grounded theory research and refers to the coding of interview passages that have significant meaning in the context of the particular research focus (Corbin & Strauss, 2012, 2008; Gioia et al., 2013; Glaser & Strauss, 1967). In the next step, we combined the in vivo codes in 64 first-order, informant-centric categories. The comparison of the first-order categories enabled us to determine analogies between them and generate 22 researcher-centric second-order themes. In the final step, we consolidated the second-order themes into four aggregate dimensions. These steps allowed us to create a final data structure (Gioia et al., 2013) that Figure 4 summarizes.

Thereupon, we utilized the FPMA and iteratively compared our observed empirical patterns to the theoretical patterns of our initial flexible pattern matching template (Figure 2). The comparison of the empirical and theoretical patterns helped to (a) identify various overlaps confirming the findings from extant academic literature and (b) generate new empirical insights leading to the development of new theoretical components (Bouncken et al., 2021a, 2021b; Chiles et al., 2004). The data structure of our empirical results consists of the aggregate dimensions (1) TE drivers, (2) TE input components, (3) TE process components, and (4) TE output components, which the next section of this study analyzes further (Figure 5).

Figure 5. Data structure.





4. Results of the FPMA

In this section, we present the four aggregate dimensions that emerged from our empirical analysis. We also establish the reference to the theoretical elaborations that our initial flexible pattern matching template summarized (Figure 2) at the respective paragraphs. At the end of this section, we illustrate the TE process framework in SMEs by combining our theoretical and empirical findings.

4.1. TE drivers

Previous research has partially dealt with the potential key indicative elements of transformation but has not extensively studied TE drivers in particular; therefore, we could not include this aspect in our initial theoretical flexible pattern matching template prior to collecting our empirical observations. In this context, considering TE drivers enriches existing theory about TE activities in SMEs.

As our data structure in Figure 5 shows, the identified TE drivers consist of seven second-order themes: (a) innovation-related drivers, (b) flexibility-related drivers, (c) timing-related drivers, (d) market-related drivers, (e) regulatory and political drivers, (f) financial drivers, and (g) social (media) drivers (Figure 5). The sections below explain each of these themes.

4.1.1. Innovation-related drivers

Innovation-related drivers are crucial enablers for the successful implementation of TE activities in SMEs. An organization must create an appropriate environment, in which the motivation and willingness to work on innovative subjects are at the highest possible level. According to our

empirical observations, making good ideas visible within the organization and enabling the evaluation and implementation of these ideas in an entrepreneurial way are equally important. This particularly requires the establishment of a healthy balance between creating freedom to try out these ideas and linking innovative ideas to business cases, according to their potential. Linking an idea to a business case too early can neglect its less obvious potential at the beginning. Likewise, a strong expectation established too fast concerning the idea's potential may overvalue a possible moderately good idea. Moreover, the extent of ambidextrous penetration in the organization is another innovation-related driver. An interviewee describes (from his organization's point of view) significantly driving innovation-related activities by combining the existing standard product-development processes with the generation of disruptive ideas, in collaboration with startups. Above all, collaborating with partners or startups makes resources and capabilities, such as technology and data-science-related know-how, available very quickly, to implement TE activities more efficiently. Further details and corresponding quotes from the interviewees are compared in Table 3.

4.1.2. Flexibility-related drivers

Items within the second-order theme—flexibility-related drivers—enable SMEs to accelerate the utilization of innovative TE activities by maintaining flexible and agile internal processes and decisions. The importance of the organizational disruptiveness level is one of the notable aspects that our interviewees discussed as controversial. Some interviewees evaluate the level of disruptiveness within their organizations as very high and necessary for sustainable process optimization that allows speeding up the planned TE activities. On the other hand, other interviewees argued that the rather limited level of disruptiveness of SMEs in the manufacturing industry is due to the conservative nature of this industry. However, in the long run, the opportunities for increasing the level of disruptiveness are present. Furthermore, the acceptance of a trial-and-error approach significantly influences the flexibility-related drivers. According to IP08, SMEs must consider that “when you innovate, not every idea you work on will end up successful” (IP08, Managing Director). Another interviewee added that the successful implementation of TE activities “is a trial-and-error way,” and “you have to somehow know in your head where you want to go, but only roughly,” when initiating TE (IP02, Managing Director). Therefore, the success of TE crucially requires establishing a culture that is highly flexible and accepts failures within the organization. An interviewee states that as a crucial prerequisite for a high level of freedom and flexibility in an SME, “You have to be able to handle freedom, and many can't handle freedom, if you tell them ‘now you have to decide’” (IP02, Managing Director). He further adds that “not everyone is born to be very flexible,” and, currently, this especially is an important learning process for SMEs. As interviewee IP14 stated, “There are many advantages in terms of agility and speed that medium-sized companies can at least utilize” (IP14, Director). Another interviewee addressed appropriately considering company size when reasoning how to depict agility in SMEs, compared to larger organizations. In summary, the existence of an appropriate degree of flexibility-related drivers is significant for the success of TE activities. Table 4 highlights and compares the corresponding quotes from interviewees.

4.1.3. Timing-related drivers

Timing-related drivers are another relevant TE driver the interviewees specified. Being a pioneer or a follower in the market can decisively influence the success of TE initiatives. Waiting too long to examine how the market develops leads to the risk of losing the connection and being unable to catch up with competitors. Interviewee IP16 adds that SMEs “have to strike a good balance in order to also be successful as quickly as possible, but still have the pioneering role” (IP16, Reliability Engineering Manager). The key to success is in the right timing of TE activities. Furthermore, the slow implementation of TE activities can be an obstacle rather than a driver for fruitful implementation of new technologies. Also stated was that the implementation process of a new technology can take an exceptionally long time, despite the enthusiasm of all involved stakeholders in the organization about the roll-out at the beginning. This leads to the conclusion that enthusiasm alone is not sufficient to successfully implement TE activities; there must also be

Table 3. Further Details—Innovation-related Drivers

First-Order Category	Key Findings	Quotes from Interviewees
Willingness and motivation for innovative TE activities	One of the important first-order categories is the willingness and motivation to initiate TE activities. In this regard, an interviewee describes the generation of suitable prerequisites as a significant driver.	“So looking inwardly, we have created many, many prerequisites over the past four years so that technology-driven entrepreneurship can be lived. (...) I think we already have the best prerequisites for this” (IP15, Business Development Manager).
Required essential resources and capabilities for innovation	Another relevant innovation-related driver is the availability of essential resources and capabilities within an organization. Overall, this driver is necessary for the successful implementation of TE processes in SMEs.	“These are different skills and capabilities that you need there for this kind of activities. But it just has to be right in the company” (IP16, Reliability Engineering Manager).
	According to an interviewee, the understanding of technologies and the availability of knowledge in data science is highly required for generating new digital products or enhancing customer relationships based on innovation solutions.	“Keyword data science. (...) It’s about creating new customer interfaces for digital products. (...) I would say what’s important is that you understand existing technologies and emerging technologies and try to build skills and capabilities there, and then use those to create new products” (IP08, Managing Director).
	Additionally, such resources as investments in research and development and availability of sufficient budget are essential innovation-related drivers.	“We have very high development budget, a very high research and development rate that allows us to try innovative things” (IP15, Business Development Manager).
Limitations of idea-generation process	The limitation of idea generation for TE activities can severely impede the innovation power of an SME. Based on our empirical observations, two key circumstances exist in which the idea-generation process can be limited. An interviewed corporate executive said that the non-existence of opportunities for employees to have specific time windows in which they can purely focus on generating ideas for TE activities is one of the limitations.	“But then, does the employee—who normally has a job that is structured in its tasks and so on—does he even have the time to still be the entrepreneur and then take the time to work on new ideas for this topic?” (IP02, Managing Director).
	The second main reason for limits on the idea-generation process is the excessive complexity of the idea-suggestion system and process within an organization.	“What I completely miss is something like a suitable company idea-suggestion system. And with us, I did it myself, there was an idea to put it in there. That’s not so much fun for the person who puts the idea in there. You have to describe a lot and write a lot of texts” (IP07, Vice President).

(Continued)

First-Order Category	Key Findings	Quotes from Interviewees
Linkage of ideas to business cases & Implementation of idea-validation activities	Interviewees have controversial views when assessing the relevance of linking ideas to business cases in a too-early stage. One opinion goes in the direction that alongside desirability and feasibility of ideas, it is also crucial to link the ideas to business cases as early as possible in the decision-making process and to implement an idea-validation process within the organization.	"But with every idea that we check, we look at the desirability relatively quickly. That means, do customers ask for such a solution? Second point is technical feasibility so you can technically develop this thing. And the third, is there a profitable business case behind it or can there be a profitable business case behind, the so-called viability. That means we check these three levels as soon as possible or should call them up as soon as possible" (IP08, Managing Director).
	In comparison, the following statement from another interview represents an important counterargument that a too-early linkage of ideas to business cases can prevent the successful utilization of TE activities. Overall, the linkage of an idea for a new TE activity to a business case can be an important innovation-related driver for the TE process. The important prerequisite is for more in-depth analysis regarding the long-term business potential of ideas if a business case exhibits low maturity degree in certain areas in the early development stage.	"But for some reasons the business case doesn't fly and then ideas that are actually not bad disappear back into the drawer because people say it's not worth it. Although perhaps the full potential was not yet visible, or because the idea was not yet fully developed, there might be other topics that you hadn't thought of before" (IP07, Vice President).
Extent of ambidexterity penetration	The extent of ambidexterity penetration in an organization is a further innovation-related driver. An interviewee describes from his organization's point of view that the innovation-related activities can be significantly driven by combining the existing standard product-development processes with the generation of disruptive ideas, in collaboration with internal and external startups.	"So we have the following principle of ambidexterity. Once there is this standard development. We have product lines that work, where we know that this works. But to initiate new topics, we also pursue the incubation of internal startups. (...) Of course, there are also approaches to run them completely externally or somewhere hybrid in between" (IP09, Innovation Manager).

a certain roadmap. Some observations have shown that a long-term implementation of TE activities can make an organization sustainably successful. The corresponding quotes from our interviewees appear in Table 5.

4.1.4. Market-related drivers

An additional TE driver is market-related drivers, consisting of the component's customer, market, and competitor view (Table 6). Starting with the customer view, the creation of an understanding of customer benefits and values is highly important for successfully utilizing TE activities. Our research has shown that an organization's focus on being the market leader, in terms of conducting sustainable technology-driven activities, is an important component for increasing customer benefit. Thereby, the technology itself is not the primary criterion for increasing customer benefit. Rather, first figuring out the customer's needs, then afterward deciding which technology to consider to meet customer expectations, is crucial. In addition, TE activities are also an important vehicle for the acquisition of new customers and to further strengthen customer relations.

Table 4. Further Details—Flexibility-related Drivers

First-Order Category	Key Findings	Quotes from Interviewees
Organizational disruptiveness	The significance of organizational disruptiveness level was discussed as controversial by our interview partners. Some interviewees evaluate the level of disruptiveness within their organizations as very high and necessary for sustainable process optimization that allows speeding up the planned TE activities.	“So I would say the level of disruptiveness is a very, very high one in my opinion” (IP09, Innovation Manager); “And I believe that this high extent of disruptiveness will also lead to major changes and process changes in the long term, inevitably” (IP10, Senior Director).
	On the other hand, other interviewees argue that the level of disruptiveness of SMEs in the manufacturing industry is rather limited due to the conservative nature of this industry. In the long run, however, the opportunities for increasing the level of disruptiveness are there.	“The degree of disruptiveness is extremely difficult to motivate and argue internally because, let’s say, a family business is a bit more conservative. (...) That’s why it’s probably easier to take smaller steps” (IP09, Innovation Manager). “Basically to mention the influence on our business model and technology-related entrepreneurship activities, it’s just that we operate in a very conservative industry environment (...). Of course, there are one or two things that certainly do, but that is then again rather very long-term” (IP13, Head of Digitalization).
Acceptance of trial-and-error approach	Furthermore, the acceptance of a trial-and-error approach has a significant influence on the flexibility-related drivers. According to IP08, SMEs must consider that “when you innovate, not every idea you work on will end up successful” (IP08, Managing Director).	
	Another interviewee adds that the successful implementation of TE activities “is a trial-and-error way” and “you have to somehow know in your head where you want to go, but only roughly” when initiating TE (IP02, Managing Director).	
	Therefore, for the success of TE, it is crucial to establish a culture that is highly flexible and accepts failures within the organization.	“I believe that we also have a relatively fault-tolerant culture. Of course, this can always happen in individual cases, and let’s not fool ourselves. Even with us, certain things simply go wrong from time to time” (IP06, Advisor to the CDO).
Degree of organizational freedom and flexibility	As a crucial prerequisite for a high level of freedom and flexibility in an SME, an interviewee states that “you have to be able to handle freedom, and many can’t handle freedom, if you tell them ‘now you have to decide’” (IP02, Managing Director). He further adds that “not everyone is born to be very flexible” and this especially is an important learning process for SMEs currently.	
Degree of business agility	As interviewee IP14 stated, “there are many advantages in terms of agility and speed that medium-sized companies can at least utilize” (IP14, Director).	
	Another interviewee also addresses the aspect of company size when reasoning the way to depict agility in SMEs compared to larger organizations.	“When we talk about the topic of agility, how big are such structures in a large corporation and, then again’ how can I map that in a small one” (IP12, Managing Director).

(Continued)

First-Order Category	Key Findings	Quotes from Interviewees
	Moreover, interviewee IP02 distinguishes between varying degrees of agility at the SME headquarters and the spin-off of innovative startups. The interviewee highlights that the startups are more agile than the headquarters but follow much more clearly defined guard rails.	“With startups, you don’t have to do that, and you can basically update things in a much more agile way. Of course, you still must structure something, but you’re not bound by formalities the way headquarters is. (. . .) So, the guard rails are much clearer. But you can of course move flexibly within the guard rails” (IP02, Managing Director).

Table 5. Further details—Timing-related drivers

First-Order Category	Key Findings	Quotes from Interviewees
Influence of follower/pioneer approach & Right timing	An interviewee stated an example where the company has rested on its past innovation-related success and gave less priority to the implementation of TE activities, leading to a shift from being a market leader to a follower.	“There was the innovation, then the network was really lived up to for 20 years and they rested on their laurels a bit. And that’s actually something, that’s why we’re now more in this follower situation with other products” (IP07, Vice President).
	This is why interviewee IP16 states that the early focus on TE activities is crucial for the success of these initiatives.	“The earlier and the more self-driven innovative TE activities come out of the company, the more successful the implementation will be” (IP16, Reliability Engineering Manager).
	Waiting too long to examine how the market develops leads to the risk of losing the connection and not being able to catch up with competitors.	“Of course, I can wait until the market develops and then follow this trend somewhere, if I manage to follow at all because the others are perhaps already too far ahead” (IP16, Reliability Engineering Manager).
	Interviewee IP16 further adds that SMEs “have to strike a good balance in order to also be successful as quickly as possible, but still have the pioneering role” (IP16, Reliability Engineering Manager). The key to success is seen in the right timing of TE activities.	
Slow implementation of TE activities	An interviewee states that the implementation process of a new technology can take an exceptionally long time, despite all involved stakeholders in the organization being enthusiastic about the roll-out at the beginning.	“Word gets around very, very quickly and everyone joins the discussion, everyone thinks it’s important and right, but then no one really wants to do it. (. . .) It took a relatively long time. It was a relatively large gap between the positive propaganda and the actual implementation” (IP01, Managing Director).
	According to another interviewee “this is the point where many companies struggle or take much more time and effort to learn how to cope with it and implement the new technology” (IP17, Director).	
Long-term approaches and sustainability	In contrast to this, an interviewee mentioned that the long-term implementation of TE activities makes their organization more successful due to the sustainable mindset behind it.	“That is then again rather very long-term. That’s what makes us successful in a sustainable way” (IP13, Head of Digitalization).

Table 6. Further Details—Market-related Drivers

First-Order Category	Key Findings	Quotes from Interviewees
<p>Customer view: Understanding customer benefits and values, Transparency creation for customers</p>	<p>Interviewee IP03 mentions that their focus on being the market leader, in terms of conducting sustainable technology-driven activities, is an important component for increasing customer benefit.</p>	<p>“That we are always at the forefront on the product side, both technologically and sustainably (...), that we can increase customer benefits” (IP03, Managing Director).</p>
	<p>Another interviewee adds that the technology itself is not the primary criterion for increasing customer benefit. Rather, it is crucial to first figure out customer needs and, then afterward, to decide which technology to consider to meet customer expectations.</p>	<p>“We wouldn’t look at technology up front now, but rather say, how can we better meet customer needs and what are our means to that end? And if that’s a specific technology, that’s fine” (IP04, Head of Digital Innovation).</p>
	<p>In addition to that, TE activities are also an important vehicle for the acquisition of new customers and to further strengthen customer relations.</p>	<p>“It’s a new way to create new values for our customers. (...) So even the customer themselves, if they are able to catch additional or significant benefit out of these disrupted technologies, then they will take the chance to switch to the new supplier” (IP17, Director).</p>
	<p>Creating appropriate transparency for the customers by considering various online platforms is another important aspect. Thus, the customers can learn more about the TE activities but also the new products or services resulting from the utilization of disrupted technologies.</p>	<p>“Today we have many more options thanks to the internet” (IP11, Head of Customer Excellence).</p>
<p>Market view: Market conservatism and maturity & Market capacity and growth opportunities</p>	<p>Various interviewees stated that the conservatism and maturity of the market have a significant influence on the favorable outcome of TE initiatives.</p>	<p>“The market is basically already very, very traditional” (IP07, Vice President). “The degree of disruptiveness is extremely difficult to motivate and argue internally because, let’s say, a family business is a bit more conservative” (IP09, Innovation Manager); “Basically to mention the influence on our business model and technology-related entrepreneurship activities, it’s just that we operate in a very conservative industry environment” (IP13, Head of Digitalization).</p>
	<p>According to IP16, the segment-specific characteristics, such as dependency on local installations and products with very long-life cycles, can serve as a barrier to TE activities.</p>	<p>“But it’s still the case today, and there will continue to be some companies and industries where you go conventional. Where there are simply reasons for saying that you are dependent on local installations” (IP16, Reliability Engineering Manager).</p>
	<p>Another interviewee adds that generally, all SMEs are in the exploration and early adaptation phase when considering the maturity of TE activities.</p>	<p>“Every player is in the early adaptation phase. They are working with early adopters, but the overall maturity is not there yet. So it’s more in terms of exploring things” (IP17, Director).</p>

(Continued)

First-Order Category	Key Findings	Quotes from Interviewees
	Interviewee IP08 states that especially there are growth opportunities on the market, by extending current products with digital features and developing new digital products.	“What many companies in Germany are lacking and where these technology-driven activities should contribute to this, is the development of digital products around them. In other words, how can these hard products be supplemented with digital products?” (IP08, Managing Director).
	Likewise, interviewee IP12 mentions that these kinds of TE activities are accelerating the growth potential in the market.	“If you offer these opportunities, you will be able to grow significantly above the market. And I would even say that regardless of the industries in which you are active” (IP12, Managing Director).
	According to interviewee IP15, TE activities can also influence the market capacity by optimizing internal manufacturing procedures. With the help of disruptive technologies, the existing redundant capacity in the market can be used by making the production plants and corresponding processes more efficient.	“We actually have quite a lot of redundant capacity in the market. If we could now manage to make the plants and the processes around them more efficient with technologies, then we would be able to use this capacity” (IP15, Business Development Manager).
Competition view: Role of global competition & Risks leading to competitive disadvantages	Interviewee IP03 states that companies operating in countries outside of Germany have a competitive advantage due to more informal interaction with the TE-related innovation activities.	“Other countries do things a bit more loosely, and I think that gives them a competitive advantage. Especially now in fields of innovation” (IP03, Managing Director).
	Additionally, interviewee IP06 says that specifically foreign competitors put German SMEs under certain pressure regarding the successful utilization of TE activities.	“The fact that we, as a globally operating company, are in an enormous area of tension, also with the competition from Asia or the other manufacturers from further countries, who are also making themselves broader and broader in the market, also acting globally, means that we are, of course, under constant pressure” (IP06, Advisor to the CDO).

A deeper look into the market view shows that the conservatism and maturity of the market significantly influence the favorable outcome of TE initiatives. The aspect of conservatism was likewise mentioned previously as a relevant criterion regarding the flexibility-related drivers. Furthermore, segment-specific characteristics, such as dependency on local installations and products with very long-life cycles, can serve as a barrier to TE activities since the willingness to innovate is at a relatively low level in these cases. Moreover, we identified additional empirical observations concerning the weight of market capacities and growth opportunities on driving TE activities. Our research revealed that growth opportunities in the market especially center on extending current products with digital features and developing new digital products. Further observations indicated that TE activities can also influence the market capacity by optimizing internal manufacturing procedures. With the help of disruptive technologies, the existing redundant capacity in the market can become useful by making the production plants and

corresponding processes more efficient. Paying particular attention to the role of global competition and the rising risk of potential competitive disadvantages, our findings highlight that companies operating in countries outside of Germany have a competitive advantage, due to more informal interaction with TE-related innovation activities. When German SMEs interact with TE-related innovation, unlike in other innovation-driven countries, the highly regulated market represents a potential barrier to the expected accomplishment of TE activities, due to its too-formal processes and approaches, as well as significant restrictions. The next section explains these regulatory restrictions in particular in more detail. Table 6 summarizes the corresponding quotes related to the market-related drivers.

4.1.5. *Regulatory and political drivers*

As the previous section mentioned, when examining the influence of regulatory and political drivers on TE activities, we have identified this first-order category serving as a driver but also as an obstacle for German SMEs. The research findings show that on one side, German regulations enable a high level of stability for SMEs; on the other side, they slow down the implementation process of innovative TE initiatives, due to strongly developed bureaucracy and substantial requirements for data protection. Further, the results highlight that the environment for driving TE activities is not mature enough in Germany yet, compared to other innovative countries. According to interviewee IP06 (Advisor to the CDO), on the other side, a “big advantage (...) in Germany as a whole is an incredible density of good universities,” allowing SMEs to recruit highly talented employees from application-related fields, to successfully drive TE activities. Furthermore, we also identified that regulatory requirements for the energy efficiency of products indirectly drive innovation in a significant way. In this context, utilizing disruptive technologies, such as artificial intelligence leading to a high focus on these technologies, can meet highly challenging government requirements. Furthermore, important interfaces exist between this driver and the TE drivers presented in the previous sections. The importance of the previously introduced drivers for the TE process can be strengthened or diminished depending on the characteristics of the regulatory and political circumstances in a country. If the circumstances are suitable for TE activities, the weight and efficiency of other TE drivers can be significantly increased, or, vice versa, decreased. Further examples and quotes from the interviewees appear in Table 7.

4.1.6. *Financial drivers*

Based on our empirical observations, we have identified appropriate financial investments as a TE driver when applied to a healthy extent. Some interviewees stated that financial investments of SMEs in technology-driven entrepreneurship initiatives are an important prerequisite, without expecting a too-early return on investment. Too low an investment and an inclination toward too-strong a return on investment can inhibit TE activities. Especially in smaller-sized SMEs, the duration of the investments must be very well considered and planned, to continue or stop certain investments in time, according to suitable indicators. When estimating the cost of specific investments for TE initiatives, focusing not only on the expected financial return but also on the expected increase in process-related efficiencies is crucial. Additionally, the implementation of certain TE-driving KPIs, such as submitting a certain number of innovative ideas, can lead to higher organizational motivation to conduct TE activities and push various departments to generate innovative TE-related ideas. Table 8 highlights the examples and interview passages resulting from our empirical observations.

4.1.7. *Social (Media) drivers*

Our empirical observations have shown that drivers related to social media platforms can push the success of TE activities in a noteworthy way. The appropriate use of social platforms can accelerate customer awareness about innovations within a company. Another observation indicates that marketing activities on different social platforms are crucial for the perceived benefit of products or services resulting from TE activities. Likewise, Table 9 summarizes the results regarding social (media) drivers.

Table 7. Further Details—Regulatory and political drivers

First-Order Category	Key Findings	Quotes from Interviewees
External opportunities and challenges for TE activities	Interviewee IP03 stated that on the one side German regulations are enabling high stability for SMEs, and on the other side, they slow down the implementation process of innovative TE initiatives, due to strongly developed bureaucracy and high requirements for data protection.	"So on the one hand, I think we have a very good environment because we have a lot of stability and continuity here in Germany. However, we have so many regulations, so much bureaucracy, which puts many, many obstacles in the way of innovation. Whether it's data protection, which is certainly justified, but which is also an obstacle to innovation in certain areas" (IP03, Managing Director).
	Likewise, interviewee IP17 explains that the environment for driving TE activities is not mature enough in Germany yet, compared to other innovation-driven countries.	"In Germany, maybe the environment for innovations is not fully ready to cover the whole industries. Therefore, they are where then other country clusters are in a more advanced level in that sense" (IP17, Director).
	Interviewee IP15 further adds that the politicians already recognize this existing challenge in Germany and, therefore, are rethinking certain processes.	"I think politicians have understood that we need a different entrepreneurial culture. And we also need to try out completely different innovative things entrepreneurially" (IP15, Business Development Manager).
	According to interviewee IP06 (Advisor to the CDO), a "big advantage (...) in Germany as a whole is an incredible density of good universities" allowing SMEs to recruit very good employees from application-related fields in particular and to successfully drive TE activities.	
	Additionally, interviewee IP14 expresses that "German medium-sized companies are per se mostly successful because of certain technology-driven entrepreneurial activities, which may also date back a relatively long time" (IP14, Director).	
Regulatory requirements & Energy and global warming	Furthermore, we also identified that regulatory requirements regarding the energy efficiency of products is indirectly driving the innovation in a significant way. In this context, interviewee IP17 mentions that these governmental requirements are highly challenging and can be met by utilizing disruptive technologies, such as artificial intelligence.	"There are a lot of this governmental driven initiatives in each country where it's becoming more and more enhanced in terms of regulatory requirements and for companies to fulfill this net zero emission topics. It cannot be done with hardware, but companies have to somehow implement this AI technology to further optimize" (IP17, Director).
	Interviewee IP01 goes one step further and explains that due to too-strict regulations, the only possibility to drive innovative TE activities is to enhance the product itself.	"In other words, the only innovation opportunity we really have is to improve the machine itself so that the process becomes more stable, more efficient, more economical" (IP01, Managing Director).

Table 8. Further Details—Financial Drivers

First-Order Category	Key Findings	Quotes from Interviewees
Focus on ROI & financial resources	<p>Some interviewees stated that financial investments of SMEs in technology-driven entrepreneurship initiatives is an important pre-requisite without having a too-early return on investment expectation. In the following, we cited two examples from the interviews.</p> <p>A too-low investment and too-strong return on investment inclination can be inhibiting for TE activities.</p>	<p>“And I believe that family businesses in particular are also in a position to have the staying power and not to expect a return on investment in the second or third year” (IP06, Advisor to the CDO);</p> <p>“The question is what opportunities a rather small or medium-sized company has to develop further in this area. On the one hand, we are talking about the financial resources that I need for this. In some cases, as we have experienced firsthand, this involves very, very large investments, whose return tends to be rather uncertain because we are, of course, also moving into new territory” (IP12, Managing Director).</p>
	<p>As also mentioned by interviewee IP02, due to the smaller size of SMEs, the duration of the investments must be very well thought through and planned, in order to continue or stop certain investments in time, according to suitable indicators.</p>	<p>“But we’re not so big that we’re now paying for ten years of basic research for technology-driven activities” (IP02, Managing Director).</p>
Dealing with costs	<p>Estimating the cost of specific investments for TE initiatives also requires focusing not only on the expected financial return but also on the expected increase in process-related efficiencies.</p> <p>Interviewee IP03 states that his company was able to automate and standardize certain processes to a degree that the savings are higher than the cost of the TE initiative at the end.</p>	<p>“And on the other hand, it costs much, much more if someone always reads by hand, thinks about what they have to do and then responds to requests in an individual way, than if I can process this in a standardized and automated way” (IP03, Managing Director).</p>
	<p>In this context, interviewee IP15 suggests a mechanism to measure the benefit of a TE activity and then to let the department or startup from which the success is coming share in the success.</p>	<p>“Ideally, you have the mechanism to check whether the benefit, which was performed there, so to speak, by the startup or the function to monitor and then to say, startup you profit to that specific level from it so that a direct profit-sharing is also given” (IP15, Business Development Manager).</p>
Usage of TE-related KPIs	<p>Additionally, interviewee IP07 shares his idea to implement certain TE-related KPIs in SMEs in order to motivate and push various departments to generate innovative ideas for TE activities.</p>	<p>“You could also make it so, for example, that each manager has to report five ideas a year from his or her team. That would be a great indicator. This would certainly help to push the topic of technology entrepreneurship forward” (IP07, Vice President).</p>

Table 9. Further Details—Social (Media) Drivers		
First-Order Category	Key Findings	Quotes from Interviewees
(Digital) marketing & social media	The appropriate use of social platforms can accelerate customer awareness about innovations within a company.	“What really surprised me was what social networks can do technically with information spreading (...). I was really surprised at how quickly the word got around and how quickly the market can get fired up about something these days, which means it’s really media-driven” (IP01, Managing Director).
	Interviewee IP14 further adds that marketing activities on different social platforms are crucial for the perceived benefit of products or services resulting from TE activities	“That is partly questionable whether it is really achieved or is just marketing. But at the edge, at the beginning, there is in any case a new data point that has managed to ultimately raise efficiencies that could not be raised before because one has not dealt effectively enough or openly enough with new technologies” (IP14, Director).

Generally, we have identified that the TE drivers both move TE activities forward with supportive measures and hinder them with overly structured processes or high expectations regarding financial and time factors. A balanced and situational mix of these TE drivers is an important condition for the successful implementation of TE activities in SMEs.

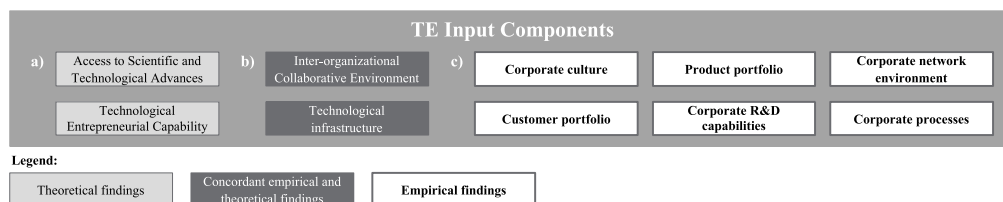
4.2. TE input components

The aggregate dimension “TE input components” consists of eight empirically identified second-order themes, two of which overlap with input components of the initial theoretical flexible pattern matching template developed early in the research. We have assigned the overlapping findings from the empirical and theoretical results to the category “concordant empirical and theoretical findings” below. Additionally, two other components were previously identified based on theoretical findings but not confirmed by our empirical results. These purely theoretical findings are assigned to the “theoretical findings” category. Following the FPMA, in the next sections, we compare the theoretical and empirical findings and discuss similarities as well as differences. Based on this logic, the next sections comprise three parts: (a) theoretical findings, (b) concordant empirical and theoretical findings, and (c) empirical findings. Figure 6 illustrates the TE input components.

4.2.1. Theoretical findings

We gathered two TE input components that the extant academic literature listed, but our interviews did not cover: (a) access to scientific and technological advances and (b) technological entrepreneurial capability. According to Chaston (2017), access to scientific and technological advances is one of the relevant TE input components. This component especially supports organizations that aim to utilize TE activities and want to overcome the associated challenges by

Figure 6. TE Input Components.



creating a link to existing knowledge related to specific technologies and scientific contributions. Furthermore, Chaston (2017) highlights the technological entrepreneurial capability as an additional TE input component. The availability of a great extent of suitable technological capabilities within an organization enables the successful implementation of innovation-related activities (Ritter & Gemünden, 2003). In this context, firms likewise must ensure the existence and development of adequate human-related capabilities that enable them to firmly establish technology-driven activities (Korherr & Kanbach, 2021). Both input components extracted from the literature are also relevant in the context of TE activities in SMEs. Therefore, we will consider those in our final framework.

4.2.2. *Concordant empirical and theoretical findings*

Both our literature analysis and empirical observations determined the following TE input components: (a) interorganizational collaborative environment and (b) technological infrastructure. According to current academic literature, the interorganizational collaborative environment is an input component that must be considered when conducting TE activities (Chaston, 2017). Focusing on interorganizational collaborations can utilize and supplement the internal resources and capabilities of a firm, such as competencies and technologies (Greco et al., 2020). Likewise, our empirical findings highlight the importance of an interorganizational collaborative environment. Interviewee IP15 stated that for TE activities, interdisciplinary teams are “essential insofar as a company also can only be created on an interdisciplinary basis” (IP15, Business Development Manager). In addition, another interviewee notes that the creation of interdisciplinary teams is difficult in SMEs due to the smaller number of employees and the advantage of interorganizational collaboration being a long-term result instead: “If I only have two people who can really deal with the subject, then it becomes difficult with interdisciplinary, because you don’t get very far with two people. (...) It’s simply a very long way to implement technologies in interdisciplinary teams at medium-sized companies” (IP13, Head of Digitalization). In this context, further empirical findings show that a TE strategy transparent to all involved stakeholders must also be available. “Simply packing smart people together is unfortunately not enough” to carry out TE initiatives successfully, according to interviewee IP08. For the case that requires human resources for interorganizational collaboration that a firm does not have, our empirical observations show that SMEs focus on hiring new talent or training existing employees. In this regard, interviewee IP12 states that it is more challenging for SMEs to hire very good talent compared to large firms: “And when we see how difficult it is to find the right qualified employees in a wide variety of areas, then of course as a large corporation you often have better chances of attracting these talents” (IP12, Managing Director).

Chaston (2017) points to the technological infrastructure as another input component of TE. Not only for carrying out TE activities successfully but also for significant economic growth, the technological infrastructure takes on a fundamental role (Freeman, 2004). In addition, our empirical observations reveal that the role of software products is becoming substantially important and requires an advanced software-related technological infrastructure within SMEs. The following excerpts from our interviews underpin this: “The differentiation nowadays is much more in the software (...) that’s certainly one of the technology-driven innovations where we are at these days” (IP06, Advisor to the CDO); “We are a mechanical engineering company, but our software development department is much larger than the hardware development department” (IP02, Managing Director).

4.2.3. *Empirical findings*

The following explains in more detail the TE input components that we identified purely from our empirical observations.

The corporate culture is an important second-order theme that is a part of the aggregate dimension of TE input components. Overall, the interviewees assign strong attention to the corporate culture. The existence of a suitable culture significantly influences the success of utilizing TE activities in the organization. Based on our empirical observations, aspects such as open interaction in teams across all hierarchical levels, changes in leadership styles (e.g., from autocratic to transformational leadership) resulting from generational changes in the top management of owner-managed firms, and empowerment of individual team members can be classified under the category of corporate culture. This leads to flatter hierarchies, much more internal communication, and great freedom for the people in creating and implementing innovative ideas. In addition, especially in SMEs, recognizable resistance can occur, especially in the initial phase of TE activities where first adapting new cultural habits step-by-step must be considered. Besides, the interviewees mentioned that generational changes within SMEs can inhibit the corporate culture and may lead to slight slowdowns in utilizing TE activities. In owner-managed SMEs in which the founder is still managing the firm and setting its vision, a generational change can be synonymous with a change in corporate culture, as indicated above.

Another crucial TE input component is the SME's existing customer portfolio. In this regard, our empirical findings highlight the significance of understanding customer expectations as accurately as possible, in order to successfully carry out TE initiatives. Almost all SMEs that we considered in our sample are in a transformation process from a classical manufacturing company to a firm that wants to be much closer to its customers, with innovative solutions and TE activities. In this context, the development of new software solutions that complement the hardware products in a very intelligent way plays an especially important role. The success of this transformation process is very much related to performing an in-depth pain-point analysis of the customer portfolio. Some findings show that customers positively receive these types of measures regarding understanding customer pain points and providing technological solutions; they, in turn, perceive the companies as innovation leaders.

Regarding the product portfolio, which likewise represents a TE input component, the increasingly similar products on the market are a major challenge to the company's maintaining its image as a unique firm. The market is expecting and perceiving the ever-increasing quality of products and corresponding services. In this context, TE activities play a crucial role in maintaining or building the unique selling proposition of certain firms.

Corporate research and development (R&D) capabilities are a further important input component of TE. Our interviews identified the very important role of the R&D department; they are the ones advancing the firm's TE-related innovative activities. Furthermore, our results highlight that the R&D department consistently thinks about how existing processes and products can be even better and represents the core of TE initiatives. Ultimately, a high R&D rate and a suitable R&D budget are important prerequisites for successful TE implementation.

The corporate network environment represents an additional TE input component that we have divided into three parts: (1) collaboration with startups, (2) collaboration with universities/networks, and (3) collaboration with corporations. Collaboration with startups is a very fruitful and important success factor in conducting TE activities at SMEs, conditional upon making a suitable environment available. Therefore, many SMEs are highly active in the mergers and acquisitions (M&A) market, to acquire startups or invest in them. Another important element is collaboration with universities and specific networks. Universities especially are recognizably highly innovative, so SMEs initiate collaborations with such institutes to learn from them, as well as to fill the gap of existing TE-related know-how and capabilities. Likewise, access to experts from specific networks

helps firms to understand existing approaches or collaborate on new approaches for overcoming emerging challenges.

The last empirically identified TE input component is corporate processes, which our interviewees controversially discussed. In many of our observations, the core organization and (for instance) a newly acquired startup are separated from each other to accelerate the processes related to TE activities. Some interviews revealed that processes in the core organization are seen as too tied to formality, representing a significant obstacle for innovative TE activities. On the other hand, some observations highlighted certain processes within SMEs that can also be as advantageous for innovations. In particular, fast decision-making processes, quick budget approvals, or extremely fine-tuned processes in place allow a very well-established foundation for utilizing successful TE activities.

Further details regarding our empirical findings and the corresponding quotes from the interviewees appear in Table 10.

4.3. TE process

The third aggregate, TE processes, includes three empirically identified second-order themes, two of which overlap with the theoretically developed initial flexible pattern matching template in Figure 2. Based on our empirical observations, we could not fully validate the remaining components of the TE process. Hence, these components are purely theoretical findings in our final framework that can also apply very well to SMEs. Analogous to our approach in the previous section related to the TE input components, we match the theoretical and empirical patterns and discuss similarities as well as differences, following the FPMA. Based on this logic, the next sections comprise the three parts: (a) theoretical findings, (b) concordant empirical and theoretical findings, and (c) empirical findings. Figure 7 illustrates the TE process components.

4.3.1. Theoretical findings

Based on our theoretical findings, we identified two TE process components that are not covered by empirical observations: (a) an environmental component and (b) key activity sets of TE. According to Petti (2009), suitable environmental conditions must exist in a firm to successfully conduct technology-based activities. Likewise, Maysami et al. (2019) considered the environmental component an important element of the technological entrepreneurship ecosystem. This component represents an essential element of the TE process and is, therefore, in our framework. As already introduced in a previous section, the key activity sets of TE are likewise an important base for the ability to create new business opportunities in firms (Petti, 2009). When we generally compare these theoretical findings with our empirical observations using the FPMA, we cannot directly match them with empirical findings, but the content of the key activity sets can very well transfer to TE initiatives in SMEs. Therefore, these two components also represent a crucial element of our TE process framework.

4.3.2. Concordant empirical and theoretical findings

The following two TE process components appeared in both our literature analysis and empirical observations, namely, entrepreneurial component and management component. Petti (2009) considers the entrepreneurial component activities of individuals and companies for discovering and utilizing the extraordinary and disruptive potential of rising technologies and business opportunities. According to our empirical results, the entrepreneurial component consists of (a) change of mindset, (b) relation of a startup to the core business, and (c) human-technology collaboration. Our interviewees stated that SMEs generally should provide their employees with possibilities to develop an entrepreneurial mindset, to get them out of their well-trodden paths. This, in turn, is also a big change as the stakeholders involved must leave their comfort zone. Furthermore, some interviewees mentioned that a certain relationship must exist between the core business of SMEs and startups with which the SMEs are cooperating or which they have acquired. Mostly, SMEs have developed new business models that relate to their core business but do not completely

Table 10. Further Details—Empirical Results of TE Input Components

Second-Order Theme	First-Order Category	Key Findings	Quotes from Interviewees
Corporate Culture	Role of company culture	The role of culture has a significant influence on the success of utilizing TE activities in the organization, leading to flatter hierarchies, much more internal communication, as well as a greater extent of freedom for the people to create and implement innovative ideas. In addition, especially in SMEs, strongly recognizable resistance can occur, especially in the initial phase of TE activities.	“So that means the culture has already changed dramatically to a very innovative system. Flat hierarchies, a lot of communication with people, a lot of freedom during the development phase. (...) Of course, even in medium-sized companies, not always are the doors open for these kind of innovative initiatives” (IP02, Managing Director). “I think that’s just again a culture aspect that’s behind it than it’s really an infrastructure topic” (IP06, Advisor to the CDO); “So I would argue that I don’t know if you can call it a resource, but actually a cultural part. Culture is certainly the biggest factor in all of this” (IP14, Director).
	Role of generational change & Weight of company founder	Generational changes within SMEs can inhibit the corporate culture, which may lead to slight slowdowns in TE activities.	“I would say that the only challenge we have is that in the medium term, or rather in the short-term, we are facing a generational change, which is actually inhibiting the corporate culture a bit. Because that is always the case with medium-sized and owner-managed companies” (IP13, Head of Digitalization).
		In owner-managed SMEs in which the founder is still managing the firm and setting the vision, a generational change can be synonymous with a change in corporate culture.	“We are very, very owner-driven, because the company founder is still in the company and also sets the vision and is also significantly involved in innovative product development, but is also always pushing into new markets himself or wants to play with new technologies, which is relatively nice” (IP03, Managing Director).

(Continued)

Table10. (Continued)

Second-Order Theme	First-Order Category	Key Findings	Quotes from Interviewees
Customer portfolio	Customer's expectations	<p>Almost all SMEs in our sample are in a process of transformation from a classical manufacturing company to a firm that wants to be much closer to its customers with innovative solutions and TE activities. In this context, especially the development of new software solutions that complement the hardware products in a very intelligent way are playing an important role.</p>	<p>"We have to change from a classic machine builder to something that brings us closer to our customers, so to speak, but also brings us permanently into a relationship with our customer. (...) But more and more, customers are also expecting them to deliver the comprehensive software package and hardware machines. And I think that's certainly one of the technology-driven innovations that we're working on today" (IP06, Advisor to the CDO).</p>
		<p>The success of this transformation process is very much related to performing an in-depth pain-point analysis of the customer portfolio.</p>	<p>"So the important thing is that you have a customer who has a pain that you meet. You have to know this pain and also know what is associated with it" (IP09, Innovation Manager); "Yes, we have carried out relatively intensive pain-point analyses with our customers in order to find out, okay, where the shoe pinches, and then try to take this into account through developments" (IP12, Managing Director).</p>
	Customer's awareness about innovation level	<p>Some findings also state that these types of measures are positively received by customers, so that they, in turn, perceive the companies as innovation leaders.</p>	<p>"We conducted a customer survey. We are also the absolute innovation leader in the perception of our customers" (IP10, Senior Director).</p>
Product portfolio	Similarity of products as a challenge	<p>Regarding the product portfolio, the increasingly similar products on the market are seen as a major challenge to continue to be perceived as unique. The market expects and perceives an ever increasing quality of products and corresponding services.</p>	<p>"If you look at our machines today, they almost all look the same these days" (IP06, Advisor to the CDO); "Products become more and more comparable, they experience a higher quality and what the customer perceives is, on the one hand, the product, but on the other hand, also the service around it" (IP11, Head of Customer Excellence).</p>

(Continued)

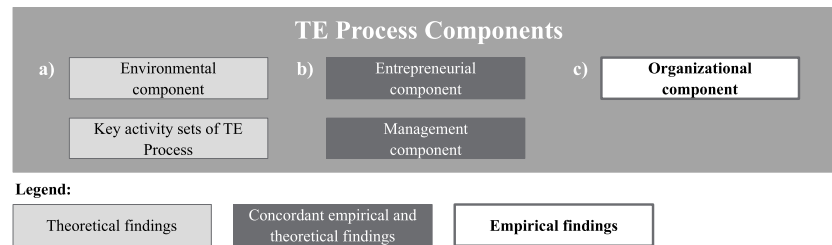
Second-Order Theme	First-Order Category	Key Findings	Quotes from Interviewees
Corporate R&D capabilities	Role of R&D	Based on our interviews, we identified that the role of the R&D department is very important; they are the ones advancing the TE-related innovative activities in firms.	“In the end, I think you can’t get around the developers, because they are the ones who advance the innovations forward, so to speak” (IP06, Advisor to the CDO).
		Our results highlight that the R&D department consistently thinks about how existing processes and products can be made even better and represents the core of TE initiatives. Ultimately, a high R&D rate and suitable budget for R&D activities are important prerequisites for successfully implementing TE.	“Of course, we also have a relatively well-staffed R&D department that is always thinking about how we can make what we are already doing even better” (IP10, Senior Director); “We have a very high development budget, a very high R&D rate, which allows us to try things out” (IP15, Business Development Manager).
Corporate network environment	Collaboration with startups	The collaboration with startups is seen as very fruitful and an important success factor for conducting TE activities within SMEs, on the condition that a suitable environment is available.	“So my understanding of technology-driven entrepreneurship would be that I, as a medium-sized company, get involved with startups myself and work together with startups or I also build a startup. (...) And we discovered relatively early on that collaboration with such startups can be very fruitful if you simply provide a certain amount of leeway” (IP15, Business Development Manager).
		This is why many SMEs are also highly active in the M&A area, to acquire startups or invest in them.	“In addition, we are, of course, also relatively active in the M&A area, and have various investments in startups that deal with the question of how we can drive innovation” (IP10, Senior Director).
	Collaboration with universities/ networks & Collaborations with corporates	Universities are recognized as innovative, so SMEs initiate collaborations with such institutes in order to also learn from them as well as fill the gap of existing TE-related know-how and capabilities.	“Which is now of course added is that we are working much more directly with universities on innovation projects of this kind. (...) Generally, universities are innovative” (IP02, Managing Director).

(Continued)

Table10. (Continued)

Second-Order Theme	First-Order Category	Key Findings	Quotes from Interviewees
		Likewise, access to experts from specific networks helps firms to understand existing approaches or collaborate on new approaches for overcoming emerging challenges.	“But also access to knowledge, to sparring partners. Some companies make use of central innovation units, ultimately make use of a network of agencies, of service providers, who perhaps also help from time to time. (...) Simply having access to experts also perhaps helps to build up networks internally, but also externally, so as not to remain in the dark for too long” (IP14, Director); “We are also in exchange with a few smaller companies with whom we have already worked well, which, for example, automatically evaluate telephone calls and distribute them correctly or also evaluate e-mails” (IP03, Managing Director).
Corporate processes	Fix processes in the core organization	To accelerate the processes that are related to TE activities carried out, in many of our observations the core organization and startups are separated from each other.	“It’s not for nothing that startups are always completely separated from larger corporates and told to do their own thing. Only then do you really get the pace on the track, so to speak” (IP06, Advisor to the CDO).
		Some interviews revealed that processes in their core organization are seen as too tied to formality, representing a significant obstacle for innovative TE activities.	“Of course, you still have to structure something, but you are not bound by formalities in the way that the head office is” (IP02, Managing Director).
		On the other hand, some observations highlighted that certain processes within SMEs can be considered strengths for innovations. In particular, fast decision-making processes, quick budget approvals, or extremely fine-tuned processes in place allow some SMEs involved in our study a very well-established foundation for utilizing successful TE activities.	“And I believe that this is perhaps also the strength of actually making decisions much more quickly in medium-sized companies, and also releasing budget much more quickly to employees in order to take a closer look at one topic or another” (IP14, Director); “SMEs, the hidden champion or Mittelstand inside Germany, they have very fine, let’s say, tuned processes embedded. And then also they are making success stories based on this” (IP17, Director).

Figure 7. TE process components.



correspond to it. Additionally, it is important to involve as many departments from the core organization as possible when working with startups. Likewise, the collaboration between humans and technology plays a significant role. According to our empirical results, the appropriate utilization of new technologies should result in employees being able to devote more time to complicated tasks that require human judgment and that technology cannot solve. This can significantly increase the efficiency of employees and, consequently, of the SME. Further details concerning the empirical results related to the entrepreneurial component appear in Table 11.

In addition, Petti (2009) highlights that the management component represents the activities of individual managers and companies required for creating a unique value proposition, enabling fast market entry to accomplish targeted business opportunities. Similarly, Korherr et al. (2022) emphasize the importance of the management component when a firm implements analytics-based or technological activities. According to our empirical results, the management component consists of seven first-order categories. An important criterion for successful TE implementation is the strong engagement of top management. For example, some interviewees mentioned that their top management regularly organizes management committees and requests information on the project and budget status, as well as actively participating in the development of TE ideas. Furthermore, the interviewees stated that the preference for a market-driven or market-push approach is another crucial management decision. Depending on the firm's aim, both approaches can lead to a successful implementation of TE activities. In cases where a company considers utilizing new and highly attractive technology, quickly introducing it to the market and being the first mover are crucial. Otherwise, other competitors would take the advantage of pioneering and gaining market shares. Waiting too long for the market to develop can make it impossible to catch up with the competition. Our interviewees stated that both directions must be appropriately considered, according to the situation. In certain situations, mainly considering customer requests (market-driven) can be relevant; other cases might require pushing certain TE initiatives from the technology direction (market-push). Another point of view in our empirical observations was that company size plays an important role. By focusing on such approaches as trend scouting, smaller companies observe the market development and the behavior of the first market entrants very early, adapting their TE strategy accordingly. The maintenance and awareness of the core value proposition in the SME's business model is a further relevant management component within the TE process. In general, our empirical results highlight especially values, such as sustainability and quality, as the key value proposition criteria that must be retained and strengthened when conducting TE activities in SMEs. For further consideration of business model transformation-related aspects, our interviews show that management must profoundly analyze particular risks and challenges, to be able to prepare appropriate countermeasures. Besides, the successful utilization of TE activities is much more than just bringing intelligent employees together. The management must ensure that the necessary skills are available, or will be through training and development within the company in the various corporate functions, so all stakeholders can work on the TE implementation in a success-oriented manner. Additionally, interviewees mentioned that management should implement TE-based business model innovation (BMI) activities as a continuous process. Many examples from our interviews show that top management tended to launch a technological innovation once, then was satisfied with the accomplishment for several years, even decades. Nowadays, markets are very dynamic, and the approach of continuously

Table 11. Further Details—Entrepreneurial Component

First-Order Category	Key Findings	Quotes from Interviewees
Change of mindset	SMEs generally should provide their employees with possibilities to develop an entrepreneurial mindset to get them out of their well-trodden paths.	“I believe that it has a lot to do with a mindset. I believe what is always important is to get people out of their well-trodden paths and to let them think in new ways” (IP06, Advisor to the CDO); “This means that employees must also be given the opportunity to develop an entrepreneurial spirit or mindset” (IP14, Director).
	This, in turn, is also a big change as the stakeholders involved must leave their comfort zone.	“That’s just a huge change, I think. It’s definitely a challenge for us, too, because of course you have to get out of the swamp a bit and out of your comfort zone. But I consider that as very important” (IP15, Business Development Manager).
Relation of startup to core business/ headquarters	A certain relationship to the core business must exist.	“So what is important to us is that we always want to have a connection to the core business. So it always has to be related to a problem, like a real startup, because we have to solve some kind of problem” (IP05, Managing Director).
	Mostly the SMEs have developed new business models that relate to the core business of the SME but do not completely correspond to it.	“And that’s why we have grown to the point where we develop new business models that are related to the core business, but do not completely correspond to the core business. That means expanding the core business by a little bit” (IP08, Managing Director).
	It is important to involve as many departments from the core organization as possible when working together with startups.	“This is then very important for the acceptance of the whole topic. We work in a matrix structure. In principle, we have the classic silos, but the incubation programs all run across the matrix. So that’s extremely important and it involves all areas, from development to marketing and sales” (IP09, Innovation Manager).
Collaboration between humans and technology	The appropriate utilization of new technologies should result in employees being able to devote more time to complicated tasks that cannot be solved by technology. This can significantly increase the efficiency of employees and consequently of the SMEs.	“The clerk never has to touch the standard process. He just gets the square eggs and has to process them because the machine can’t do that yet. But that will continue to develop, so the square eggs will become fewer and fewer” (IP03, Managing Director). “Ultimately, however, this means that in future we will only be able to do this with 10 percent of the team. (...) On the one hand, to say okay, then you actually have more time for the important things” (IP12, Managing Director).

aiming for new TE activities will lead to sustainable success. Moreover, the interviewees stated that being close to the core company strategy is very important. When developing new business models. Then, defining suitable activities enables stepwise development in the direction of new business models. As a final point regarding the management component, our empirical investigation revealed that management decisions, such as developing new products with low-cost technologies based on a second brand, could benefit the success of TE implementation. This, in turn,

Table 12. Further Details—Management Component

First-Order Category	Key Findings	Quotes from Interviewees
Role of top management	An important success criterion for TE implementation is close cooperation with top management. Some interview partners mentioned that their top management regularly organizes management committees, requests information on the project and budget status, and actively participates in the development of TE ideas.	“I report directly to the CEO and we have very regular committees where senior management is involved and receives both content and information on the project status, budget status and on the products, and also plays a very strong role in shaping this” (IP04, Head of Digital Innovation).
Role of market-driven/ market-push approach	In cases in which a company considers utilizing a new and highly attractive technology, it is crucial to quickly introduce it to the market and be the first mover. Otherwise, other competitors would take the advantage of being the pioneer and gaining market shares. Waiting too long for the market to develop accordingly can make it impossible to catch up with the competition.	“We want to put the system through its paces before we launch it on the market, but this time we have actually said, because this is simply such a hot topic, if we test it now, someone will take the butter off our bread. (...) On the one hand, it’s market-driven, and on the other hand, this technological development is helping to steer the market somewhere, because we were the first to be able to offer three alternatives now” (IP01, Managing Director); “Either I can innovate myself or, of course, I can wait until the market develops and then follow this trend somewhere. In quotation marks, if I manage to follow it at all, because the others are perhaps already too far ahead. (...) I think you have to strike a good balance in order to be successful as quickly as possible, but still have the pioneering role” (IP16, Reliability Engineering Manager).
	Both directions must be appropriately considered. On the one hand, considering the customer’s request is relevant, and on the other hand, it is needed to push certain TE initiatives from the technology direction.	“So there is more or less a push and pull in innovation. And my unit is basically, we come with the customer’s request. So, we tend to pull from the customer direction. And then, of course, there is our development, which pushes more from the technology direction” (IP04, Head of Digital Innovation).
	Likewise, company size plays an important role. By focusing on such approaches as trend scouting, smaller-sized companies are observing the market development and the first market player very early.	“No, quite honestly, we are usually too small for that. We try to do good trend scouting and to know where the market is going. So to listen very early to the first ones that express something like that in the market” (IP02, Managing Director).

(Continued)

Table12. (Continued)

First-Order Category	Key Findings	Quotes from Interviewees
Core value proposition of Business Model (BM)	The maintenance and awareness of the core value proposition of the SME's business model is a further relevant management component within the TE process. In general, our empirical results highlight that especially such values as sustainability and quality are the key value proposition criteria that must be retained and strengthened when conducting TE activities.	"Machines from us run for 30 years and therefore we are very sustainable. (...) And since it is the family that builds it, we are also very interested in people having 30 years of fun with our product" (IP02, Managing Director); "So, we are rather high-priced. But the quality and durability are very important for us. (...) But with us the quality and the benefit fits very well for the customers" (IP03, Managing Director).
Evaluation of BMI-related risks and challenges	Particular risks and challenges must be profoundly analyzed by the management. Successful development of TE activities is much more than just bringing intelligent employees together. The management must ensure that the necessary skills are available or are being developed within the company in the various functions, such as sales, so all stakeholders can work on the TE implementation in a success-oriented manner.	"I actually underestimated it. I would say that developing new business models is much more complicated than originally expected. Just putting smart people together is not enough, unfortunately" (IP08, Managing Director). "It is important not only to be convinced of the product yourself or that the customer is convinced of the product, but the sales channel must also be convinced that this product works. (...) That is also a challenge, that they then need these new skills" (IP09, Innovation Manager).
Implementing BMI as a continuous process	The management should implement TE-based BMI activities as a continuous process. In many SMEs, the management tends to launch a technological innovation once and then be satisfied with it. Nowadays, markets are very dynamic, and this continuous approach will lead to sustainable success.	"However, entrepreneurship must of course also be seen in the context of the company, that one does not just assume that a company acts entrepreneurially once or also involves technology, as it happened then with some or other medium-sized companies, but that it must happen continuously" (IP14, Director).
Role of proximity to core company strategy	It is very important to be close to the strategy of the core company when developing new business models. Then, suitable activities must be defined in order to be able to develop in the direction of new business models.	"I think what's really important when you're developing new business models is that you're super close to the corporate strategy. What do they want to achieve? And then you have to take a close look at what activities I'm using to contribute to it" (IP08, Managing Director).
Importance of second brand/ low-cost products	It is also important to develop new products based on low-cost technologies with a second brand, which, in turn, are particularly suitable for markets characterized by low prices. A new second brand helps to protect the main brand of an SME, which, in most cases, stands for higher quality and prices.	"We certainly cannot compete with machines on the low-entry market, simply also from the company philosophy. (...) We are currently also trying to provide low-entry machines for the rest of the world with not so high demands, which we cannot offer from our own core brand, but which we have to serve if we want to survive on the world market, if we want to ultimately enter the market in terms of quantities. We are currently doing this via two brands" (IP06, Advisor to the CDO).

might particularly suit markets that low prices characterize. A new second brand helps to protect the SME's main brand, which in most cases stands for higher quality and prices. Further details and the corresponding quotes from the interviewees appear and are compared in Table 12.

4.3.3. *Empirical findings*

The organizational component is the last part of the TE process, derived entirely from empirical results. The organizational component comprises three first-order categories. The role of the organizational structure and establishment of a new business unit (BU) represents the first one. According to our empirical observations, the continuous progress of the market environment forces SMEs to adapt their internal organizational structures to remain competitive. This demands that SMEs appropriately shape their organizational design according to market needs and be able to react to market opportunities in a suitable manner. In addition, the establishment of a new innovative BU, deliberately kept remote from the core organization and relatively independent of group specifications, is another important component of the TE process. As mentioned previously, the distance between the core business and a new BU must be finely selected, depending on existing conditions. The second first-order category related to the organizational component is the topic of releasing employees for TE activities. Our interviewees mentioned that SMEs must release suitable employees for TE activities, so they can work full time on innovative topics. As stated, the selected and released coworkers should work in the newly established BU, separate from the core organization. Changing and automating certain corporate processes represents the final element of the organizational component. Our observations highlight that the utilization of TE activities will lastingly and inevitably lead to changes in organizational processes. The fact that these activities require efficient as well as automatic processes, and the customers expecting innovative processes mostly in a digital form, justify the changes. A solid, data-driven IT infrastructure within the firm is a very important prerequisite for the implementation of these points related to process optimization. Creating these preconditions is a big challenge for most SMEs, but one at which they get better over time. Likewise, the results regarding the organizational components appear in Table 13.

4.4. *TE output components*

The TE output components represent the fourth and final aggregate dimension of our analysis. This dimension consists of four purely empirically identified output components: (a) corporate-function-related outputs, (b) business-model-related outputs, (c) competitiveness-related outputs, and (d) customer-related outputs. Our empirically observed output components specifically relate to SMEs, so we no longer consider the generally valid output components listed in our initial theoretical template at this point. The following sections analyze and discuss the empirical TE output components in more detail.

4.4.1. *Corporate-function-related outputs*

Corporate-function-related outputs represent the first output component of TE. Our empirical results indicate that TE has great importance to the sales function. In particular, the development of direct sales concepts and the utilization of new technologies, such as virtual reality to introduce customers to new products without being physically present with them, are the emerging trends for TE activities in sales. Another notable point was that salespeople must understand the new products resulting from TE activities and sell them using appropriate sales techniques. The sales team, which, in most cases, has been selling similar products for several decades, must now be able to sell new technologies as well as digital products. This requires appropriate change management that causes certain rethinking in the areas of sales. Furthermore, the importance of TE to service is also a significant aspect identified by our interviewees. Especially in recent years, the products of most SMEs operating in the manufacturing industry get increasingly similar, in terms of features and look. At this point, offering certain customer-oriented services can be an important differentiation criterion for companies. In this context, SMEs ask themselves how they can utilize TE activities so the customer ideally experiences the greatest service benefit. Likewise, significant optimization potential in the inside-sales function takes TE activities into account. According to our results, innovative TE initiatives helped SMEs to overcome situations in which the inside-sales

Table 13. Further Details—Organizational Component

First-Order Category	Key Findings	Quotes from Interviewees
Role of organizational structure/ establishment of new BU	The continuous progress of the environment and demands of the market force SMEs to adapt their internal organizational structures in order to remain competitive. This enables SMEs to appropriately shape the organizational design according to the market needs and be able to react suitably to market opportunities.	“We are finding out that this continuous progress of the environment, of society, of the demands of the market is actually forcing us to adapt our structures internally so that we can remain competitive” (IP01, Managing Director).
	The establishment of a new innovative business unit deliberately kept remote from the core organization and relatively independent of group specifications is another important component of the TE process. In this context, a decisive point is convincing relevant internal resources to carry out the change process.	“We founded our own company, far away from our corporate headquarters. We (...) founded a company, which then led a startup life there for several years, relatively independent of corporate guidelines, such as value limit matrix and all the things you know from corporations. (...) And that is, of course, a process of change to inspire internal resources as well” (IP12, Managing Director).
Release employees for TE activities	SMEs need to release suitable employees for TE activities so that they can work full time on innovative topics. These selected and released coworkers should work in the newly established business unit.	“You always have to release people. Ideally, you have to put people somewhere else, maybe even locally. Simply, have your head free, do your thing” (IP06, Advisor to the CDO). “That’s exactly why we have spun off, so that projects can be taken over for a certain period of time, but then full-time. And then you have one person who shows full ownership for it” (IP08, Managing Director).
Change/ automation of processes	The utilization of TE activities will lastingly and inevitably lead to changes in organizational processes. This is justified in particular by the fact that on the one hand, these activities require efficient as well as automatic processes and the customers expect innovative processes mostly in digital form. A solid data-driven IT infrastructure within the firm is a very important prerequisite for the implementation of these points related to process optimizations.	“So there’s much happening on the processing side, on the supply side, on the sales side, that it already poses quite a challenge to our company with a very, very small customer base. And I believe that this will inevitably lead to major process changes for us in the long term” (IP10, Senior Director). “In the course of digitization, we naturally also try to design process-supporting measures, process-optimizing measures, I would say, so that ideally the customer has a high benefit from them” (IP11, Head of Customer Excellence). “We hope that the real increase in efficiency or steps toward the autonomy of plants and processes will come from data-driven innovation. And here, very strong prerequisites have also been created within the framework of the infrastructure” (IP15, Business Development Manager).

department faced a huge number of requests and data that a human being alone could not handle. Collaborations with external companies enabled developing new technologies within a very short time, to automate the customer request and data-sorting process. Another highly relevant aspect identified from our empirical observations was the importance of TE for the IT department and infrastructure. To successfully utilize TE activities in SMEs, the firms must make mid- and long-term investments in the IT infrastructure. The availability of a strong IT department and landscape represents a crucial prerequisite for being able to perform innovative TE activities appropriately. To meet those prerequisites, many interviewees stated that their IT department and infrastructure adapted accordingly and, in some cases, even rebuilt. The final component of the corporate-function-related outputs mentioned by our interviewees was the importance of TE for procurement processes, which are highly analytical and can be calculated very accurately. Therefore, many TE activities based on such technologies as AI have already been carried out in the SME's procurement departments to optimize specific processes. Further details concerning the empirical results that relate to the corporate function appear in Table 14.

4.4.2. Business-model-related outputs

The second TE output component is BM-related outputs. According to our empirical findings, several possibilities that exist for BMI in SMEs link to TE activities. Due to successfully performing TE activities in the past, some SMEs can now improve their machines with new features or applications during operations, by adding new functionalities via the software. These activities are not just about completely changing the BM but rather strengthening various BM components. Some observations highlighted an “equipment as a service” (EaaS) model that strongly relates to TE approaches and has great potential to disrupt and extend the BM of SMEs. In particular, EaaS initiatives can exploit new market potential if the actual BM is geared toward selling machines, and this market is already heavily saturated. Another crucial aspect of the TE output components is the role of the subscription model and recurring revenues. By conducting certain TE activities, a growing number of SMEs establish recurring-revenue components in their BMs and, thus, distance themselves from purely transactional business. This type of renewal in the BM establishes tremendous customer loyalty and, thus, represents sustainable competitive advantage. Further details regarding our empirical findings and the corresponding interviewees' quotes appear in Table 15.

4.4.3. Competitiveness-related outputs

Competitiveness-related outputs represent the third TE output component. According to our empirical observations, carrying out TE activities enables SMEs to act more flexibly on the market and, hence, to adapt their products and services to customer needs. SMEs particularly consider innovative technologies to achieve greater customer efficiency by optimizing and simplifying complex and slowed-down processes of customers and, thus, differentiate themselves from other market players. These types of TE activities likewise improve productivity and cost efficiency for customers by eliminating obstructive bottlenecks in manufacturing processes, for example, by utilizing AI technologies such as predictive maintenance. Overall, our empirical results show that TE activities have huge potential to enhance the reputation of SMEs and lead to the generation of competitive advantage. Further details concerning the empirical findings and quote examples from our interviewees appear in Table 16.

4.4.4. Customer-related outputs

In this section, we introduce customer-related outputs that represent the last TE output component. Some of our interviewees mentioned that they conduct TE activities to shift to new customer groups previously not in scope. The idea is to focus on a new customer base closer to the firm (e.g., end customers) and create a unique value for those customers. These kinds of changes enable the SMEs to increase sales, as well as profits, accordingly. Interviewee IP09 reasoned as follows: “We want to create value with a different customer base. So this is more a topic that focuses on end customers ... less the classic OEMs that we often equip but rather end users—that is, users of

Table 14. Further Details—Corporate-Function-Related outputs

First-Order Category	Key Findings	Quotes from Interviewees
Importance of TE for sales function	TE has the highest importance for the sales function.	“So I think the biggest impact will be probably on the distribution side” (IP03, Managing Director).
	In particular, the development toward direct sales concepts and the utilization of new technologies, such as virtual reality, to present customers with new products without being physically present with them, are the emerging trends for TE activities in sales.	“In the long term, for example, this is also a trend that is simply moving away from the fact that, especially in Germany, everything is now actually going more in the direction of direct sales. And there is also the possibility of using virtual reality at a later date, perhaps, in order to be able to explain to customers their applications directly from us, without having to travel there” (IP13, Head of Digitalization).
	Salespeople must be able to understand the new products resulting from TE activities and sell them using appropriate sales techniques. This requires change management in the company which causes certain rethinking in the areas of sales. The sales team, which in most cases has been selling similar products for several decades, must now be able to sell new technologies as well as digital products.	“If you don’t convince the sales department that it’s a good idea, it will be extremely difficult. (...) Now I come here with a new technology that the salesperson doesn’t know. Now he is supposed to sell the new thing. You first have to convince him of this. That means the benefits and then of course also showing, okay here you can generate sales with it. It can actually be better to organize a dedicated sales force that specializes only in this product” (IP09, Innovation Manager).
Importance of TE for service function	In recent years, the products of most SMEs operating in the manufacturing industry get more and more similar in terms of features and look. At this point, offering certain customer-oriented services can be an important differentiation criterion for companies. In this context, most SMEs ask themselves how they can utilize TE so that the customer ideally experiences the highest service benefit.	“I would say that the service concept will certainly differentiate us in the future. And of course, what counts is how we can use the technologies so that the customer ideally experiences a high level of service. (...) Products are becoming more and more comparable, they are experiencing higher and higher quality, and what the customer perceives is, on the one hand, the product, but on the other hand, also the service around it” (IP11, Head of Customer Excellence).
Importance of TE for inside-sales team	Innovative TE initiatives helped SMEs to overcome situations in which the inside-sales department was confronted with a huge number of requests and data that a human being alone could not handle. Through collaborations with external companies, new technologies were developed within a very short time, which automated the customer request and data-sorting process.	“But because of this, we always have the situation that we are simply confronted with e-mail quantities that cannot be handled at all, that are also really, that is illusory, you can’t even answer them. And there was now a consideration and there (...) we found a software company here, with which we get together at least an automated sorting and an automated response, which is programmed accordingly” (IP13, Head of Digitalization).

(Continued)

First-Order Category	Key Findings	Quotes from Interviewees
Importance of TE for IT department/ infrastructure	For successfully utilizing TE activities in SMEs, the firms must conduct mid- and long-term investments in the IT infrastructure. The availability of a strong IT department and landscape represents a crucial prerequisite for being able to perform innovative TE activities in an appropriate manner.	“For me, it actually starts with a reasonable IT platform. (...) So for this, a company also needs a certain affinity or willingness to say we are investing in the IT area; it needs a medium-term or long-term concept where you say, here we have a big picture. We want to develop in this direction. And then, when I have the prerequisites, I can then deal with such topics that I say I will also add the topic of artificial intelligence at some point” (IP11, Head of Customer Excellence); “The boss has said it like this before. When he looks at a company and wants to evaluate its success, he looks at the IT department, because a strong company simply depends on it, so at the moment it needs a strong IT department. On the one hand, I need someone who is able to link processes and IT together” (IP13, Head of Digitalization).
Importance of TE for procurement	The processes in the procurement department are basically very analytical and can be calculated very accurately. Therefore, many TE activities based on technologies such as AI have already been carried out in the SME's procurement departments for optimizing specific processes.	“So procurement is a general, very analytical process that can be calculated very well, that can be recorded very well stochastically. (...) So I said, that's actually a great thing for artificial intelligence” (IP13, Head of Digitalization).

technology, people who have machines with them, which we then want to realize in machine monitoring” (IP09, Innovation Manager).

4.5. TE process framework in SMEs

Our TE process framework comprises all theoretical and empirical findings that previous sections identify and present. In our study, we have structured this framework so that it applies to SMEs, in particular. The text boxes in light gray result from the theoretical findings of our study. The dark gray text boxes illustrate those components we derived from both the theoretical and empirical results (concordant empirical and theoretical findings). All components shown in the white boxes reflect those obtained purely from empirical data (see, Figure 8).

5. Discussions

Following the previous section, in which the findings from the FPMA were presented and the theoretical patterns were enriched with empirical insights, our findings are critically discussed in the following paragraphs. First, we consider components of the final TE process framework in SMEs in a more general context and divide our interviewees into three categories according to their hierarchies in their companies. We aim to understand which hierarchical group most focuses on each part of the TE process framework. Second, we contrast our FPMA results with the studies introduced in our literature review, as compiled in Table 1. At the end of this section, we summarize the key theoretical contributions of our study.

Table 15. Further Details—BM-related Outputs

First-Order Category	Key Findings	Quotes from Interviewees
Possibilities for BMI	According to our empirical findings, there are several possibilities for BMI existing in SMEs, linked to TE activities. Due to previous successfully performed TE activities, some SMEs are now able to improve their machines with new features or applications during operations by adding new functionalities via the software.	“Today, we also make machines better during operation through software updates, through new features that we give in the firmware or the application software. This means that we can actually not only try to keep our machines at the same level over their life cycle through the digitization strategy, but we can actually make them even better. (...) We can add functionalities via the software” (IP02, Managing Director).
	These activities are not just about completely changing the BM but rather strengthening various BM components.	“That is, it is not about adapting and changing the business model, but rather about strengthening the current business model components and customer values” (IP04, Head of Digital Innovation).
	An EaaS model has great potential to disrupt and extend the BM of SMEs. In particular, new market potential can be exploited with EaaS initiatives if the actual BM is geared toward selling machines, and this market is already heavily saturated.	“But our actual business model is geared toward selling machines. But if I use the capacity that already exists in the market, then I don’t sell any more machines. And it is precisely this question that can be outlined quite well in the example, namely, that an equipment as a service model is already disruptive for the actual business model, because you simply approach it differently and you then actually have to disrupt yourself in your approach in order to exploit the greater potential” (IP15, Business Development Manager).
Role of subscription model and recurring revenues	By conducting certain TE activities, more SMEs are establishing recurring revenue components in their BMs and distancing themselves from purely transactional business. This type of renewal in the business model establishes tremendous customer loyalty and, thus, represents sustainable competitive advantage.	“I think, in general, we are of course always on the lookout to see where we can generate recurring revenue in the long term. (...) What I completely overlooked in this case, however, is really this enormous bond that you build with a customer with such a business” (IP06, Advisor to the CDO); “And then, of course, this can have a very strong influence on the business models, because you can then quite clearly move away from purely transactional business to, for example, a web-based or subscription-based or whatever you want to call it, business model” (IP16, Reliability Engineering Manager).

5.1. Focus of content according to hierarchical and expertise level

According to experience level and their roles in their firms, we assigned interviewees to three different hierarchical categories. Interviewees positioned at the highest ranked levels of the firms were assigned to the “Top Management” (TM) category. Interviewees with a medium-high hierarchical position heading departments with essential connections to TE activities were assigned to “Middle Management” (MM). Finally, interviewees with a high level of expertise and specialization

Table 16. Further Details—Competitiveness-related Outputs

First-Order Category	Key Findings	Quotes from Interviewees
Possibilities for competitive advantage	According to our empirical observations, carrying out TE activities enables SMEs to act more flexibly in the market and, thus, have various possibilities for competitive advantage.	“So on the question of competitive advantage, definitely yes. The more flexibly you can act on the market, the greater the competitive advantage” (IP16, Reliability Engineering Manager).
	SMEs have considered technologies and TE activities to achieve greater customer efficiency and, thus, differentiate themselves.	“So when we’ve used technology, it’s to make our customers more efficient, to differentiate ourselves more. That’s what we use technology for” (IP04, Head of Digital Innovation).
	TE activities have huge potential to enhance the reputation of SMEs and can lead to competitive advantage.	“I would say it has definitely enhanced our reputation (...). I think it has simply given us a certain market advantage” (IP01, Managing Director).

in TE activities were assigned to the “Lower Management/TE Specialist” category (LM/TS). Table 17 summarizes the allocation of our interviewees to these three hierarchical categories.

In the second step, we analyzed the contribution of each hierarchical group to our four main aggregate dimensions (TE drivers, TE input components, TE process components, and TE output components) representing the main pillars of the final TE process framework (see, Figure 9).

A closer analysis of the distributions within the TM group shows that they are most concentrated on TE drivers (39% of TM’s total contribution), followed by TE input components (25%), and TE process components (24%). The TM group focuses least on TE output components (12%). A similar distribution is also reflected in the MM group. They are likewise most concentrated on TE drivers (36% of MM’s total contribution), followed by TE input components (23%), and TE process components (21%). However, the focus of the MM group on TE output components is not as proportionally small as the TM group (20%). The main contribution of the final group, LM/TS, is also related to drivers (35% of LM/TS’ total contribution). This group’s second-largest contribution, however, is in

Figure 8. TE process framework in SMEs.

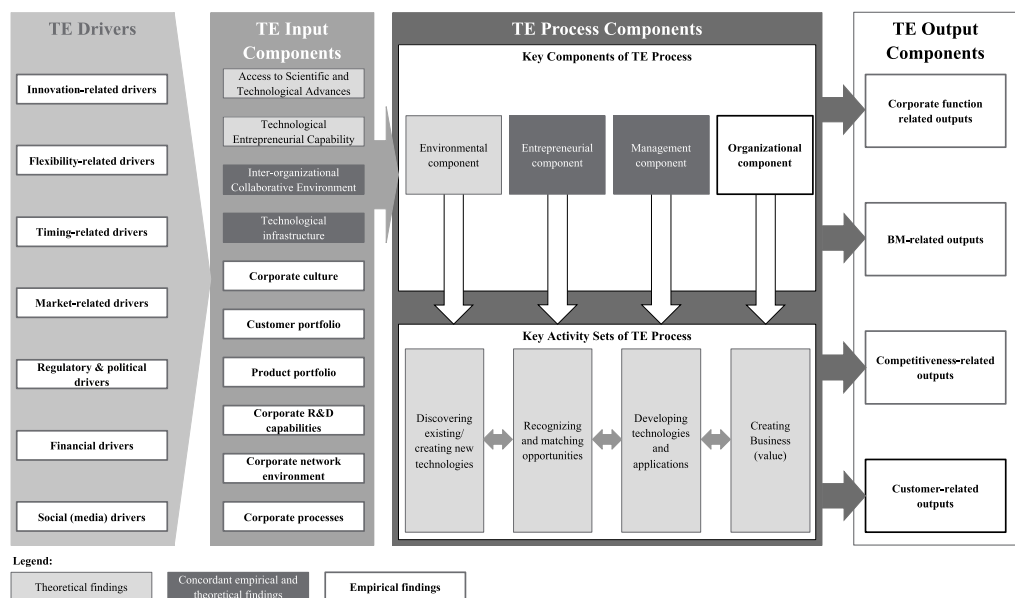


Table 17. Allocation of interviewees to hierarchical categories

ID	Role	Hierarchical Category
IP01	Managing Director	Top Management
IP02	Managing Director	Top Management
IP03	Managing Director	Top Management
IP04	Head of Digital Innovation	Middle Management
IP05	Managing Director	Top Management
IP06	Advisor to the CDO	Top Management
IP07	Vice President	Top Management
IP08	Managing Director	Top Management
IP09	Innovation Manager	Lower Management/TE Specialist
IP10	Senior Director	Top Management
IP11	Head of Customer Excellence	Middle Management
IP12	Managing Director	Top Management
IP13	Head of Digitalization	Middle Management
IP14	Director	Middle Management
IP15	Business Development Manager	Lower Management/TE Specialist
IP16	Reliability Engineering Manager	Lower Management/TE Specialist
IP17	Director	Middle Management

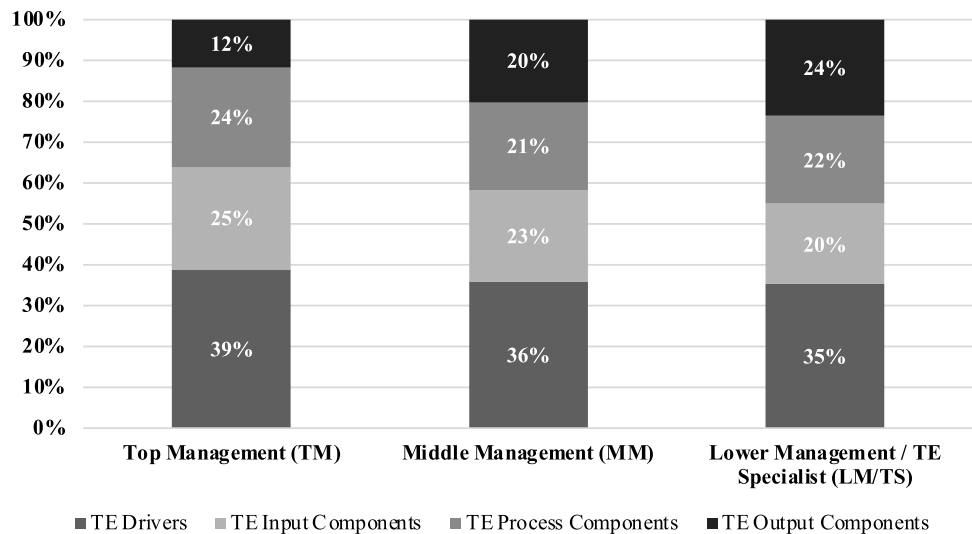
the TE output components category (24%), followed by TE process components (22%), and TE input components (20%).

This analysis reveals that as the hierarchical level decreases, the importance of the output components increases. Our empirical results particularly show that TE specialists, as well as lower-level managers, pay more attention to the output components and present the outputs generated by TE activities in a more tangible way. According to our empirical observations, managers in higher and top level positions tend to focus on ensuring the availability of appropriate drivers and resources as well as the process-related functionality of TE activities.

5.2. A comparison to the literature review

In this section, we compare and contrast our FPMA results and critically discuss the key findings.

Figure 9. Contributions of hierarchical groups to aggregate dimensions.



Hitt et al. (2001) emphasizes that smaller firms develop many entrepreneurial, breakthrough technologies compared to larger companies. Our findings provide further insights concerning the potential reasons why particular components of the TE process drive German manufacturing SMEs to implement innovative technologies. Our empirical findings reveal that certain characteristics of German SMEs, such as fast decision-making processes or the especially fine-tuned processes in place, enable a faster and more efficient utilization of TE activities compared to larger firms.

Similar to Prodan's (2011) discoveries, the input component corporate network environment of our TE process framework underlines that collaborations with other corporations (e.g., joining forces and expertise), universities (e.g., advantages of knowledge transfer), and startups (e.g., access to relevant capabilities) are an important success factor when carrying out TE activities at SMEs. A significant number of SMEs are therefore highly present in the M&A market and acquire or invest in innovative startups. These findings also contribute to filling the research gap highlighted by Cavallo et al. (2021) by further examining the collaboration of SMEs and innovative startups in terms of TE activities. Additionally, Prodan (2011) underlines that the development of TE in SMEs needs to be expedited by governments. We supplement this finding by emphasizing that regulatory and political measures can serve as a driver but also as an obstacle if incorrectly selected. The government must drive TE activities in SMEs with appropriate policies and regulations to accelerate this development.

Furthermore, Bailetti (2012) noted the relevance of TE for leaders and top managers in SMEs to create, deliver, and capture value to their stakeholders through technology. This finding is consistent with our observation that a close collaboration with top management represents an important success criterion for the implementation of TE activities. Our interviewees stated that top management must be closely involved in regular committee meetings and actively support the idea generation processes for TE activities.

In Liu et al.'s (2022) study, the authors describe the importance of effective TE management to achieve a competitive advantage and improve the performance of firms, particularly those operating in the manufacturing industry. Likewise, our empirical observations illustrate that TE activities make SMEs operating in the manufacturing industry more flexible in terms of reacting to market dynamics and, thus, provide numerous possibilities for competitive advantage.

In our theory portion, we introduced the potential key indicative elements of transformation (Chaston, 2017; Thamhain, 2003), and we will make a final reference to them here. Previous studies have focused particularly on hard indicative elements, such as number of products and services newly launched on the market or the number of patents applied for, to analyze the level of technology-driven transformation in firms. In our study, especially in relation to the TE drivers presented extensively in the previous section, we provide a detailed overview of the soft key indicative elements of transformation through TE activities. Hence, we are developing a deep understanding of the importance of drivers and soft key indicative elements when conducting TE initiatives in SMEs operating in the manufacturing industry.

5.3. Summarizing the key theoretical contributions

Our study makes two major theoretical contributions. First, it provides empirically grounded insights into the emerging TE literature. We confirm prior findings on TE theory and additionally augment new observations in the field.

Second, we develop a new TE process framework that encompasses all process core components in relation to SMEs. We highlight that certain TE drivers and input components are fundamental elements of TE initiatives that significantly affect the TE process in SMEs, as well as the resulting output components. Previous models and theories on TE referred to any company size, whereas our framework is exactly tailored to SMEs operating in the German manufacturing industry. In doing so, we make a significant contribution to the current research gaps in the SME and TE literature underlined in our literature review in Table 1. Our findings can be used as a basis for further research and provide essential ground for

academic discussions. This study contributes a new, state-of-the-art framework that meets an essential need in an increasingly growing field of academic research.

This discussion section highlights notable differences and similarities between our FPMA findings and existing academic studies and summarizes our key theoretical contributions. In our conclusions section, we specifically refer to the originality of our study and address its main managerial contributions in more detail.

6. Conclusions

In this study, we examine how technology-driven entrepreneurship processes transform the business of SMEs. For this purpose, we develop the TE process framework specifically applicable to SMEs. Our four aggregate dimensions—TE drivers, TE input components, TE process components, and TE output components—represent the core elements of the framework. The TE drivers, which have a huge influence especially on the TE input components, stimulate the TE process. Depending upon their form and the extent to which these drivers are present in SMEs, they can act as accelerators but also, in the negative case, as obstructors of the TE process. The input components basically represent the main ingredients of the core TE process and form the basis of the framework. Our empirical results show that a suitable composition of input components can exploit much new potential for value creation within SMEs. The input components directly affect the key components of the core TE process. Within that process, the key components create the ideal conditions for the key activity sets that comprise the discovery of new technologies, recognition and matching of new opportunities, development of recent technologies and applications, and creation of unique business value. Ultimately, TE output components raise opportunities for changes and shifts in various corporate functions, BM components, customer groups, and competitive relevance. As previously mentioned in the methodology section, the data on which these findings are based were analyzed and interpreted by both authors to ensure the objectivity of the research and to prevent the individual influence of each researcher using investigator triangulation (Archibald, 2016; Hair et al., 2015).

Our study is the first that develops a TE process framework for German SMEs from the manufacturing industry and analyzes its components deeply, and thus it makes a unique and original contribution to academia. Previous studies have instead dealt with the TE process in general terms and with little specific reference to particular regional conditions. Although we focused on the manufacturing industry and analyzed the specific regional setting of Germany, our final TE process framework is, to a significant extent, generalizable and likewise applicable to SMEs from other countries in the same industry. Due the global business relationships of the firms in our sample, the components and processes identified also have validity in other countries. Furthermore, our empirical patterns have shown that parts of our findings can also be applied to the service industry, as customer-oriented services can be an important differentiation criterion for companies and have relevance in the TE process. However, further analysis should be conducted to understand the extent to which our findings are applicable in other regions or industries.

Managerial implications

Based on the literature review, identified empirical patterns, and the discussion portion of this study, we have shown that a successful TE-driven transformation is strategically important for SME managers. Particularly, if a firm aims to create, deliver, and provide value to its stakeholders and customers through TE-driven innovation, managers need to be heavily involved in building and managing the TE process as well as executing corresponding activities (Bailetti, 2012; Prodan, 2011). Our results show that targeted customer focus and sustainable competitiveness is at risk if essential TE resources, capabilities, and processual components are not properly managed. In the following, we therefore summarize the most valuable managerial implications regarding the appropriate management of the TE process framework in SMEs from the manufacturing industry.

At each stage of the process, managers must consider various factors and characteristics of TE components to generate the desired business output. It starts with the fact that managers must ensure the availability of specific TE drivers. At this point, the right combination of drivers is especially important, since an improper constellation can lead to undesired results, as the findings section of this paper illustrates. Having the right TE drivers in place, practitioners can set up the input components appropriately, which, in turn, represent the foundation of the core TE process. Our results show that properly considering all these aspects can lead to achieving the expected outputs, and SMEs can transform as well as innovate their business processes using TE activities.

7. Limitations and suggestions for future research

Besides the important findings of this study, we also identify a few existing limitations and some suggestions for future research. One limitation is that our sample focuses on SMEs operating in the German manufacturing industry. We intended to derive significant theoretical and empirical findings based on a concrete understanding of TE activities in SMEs operating in this specific industry. As mentioned in our conclusions, a possible direction for further examination could be to conduct additional qualitative research focusing on other industries or geographical regions. In addition, it may be interesting to further verify our findings related to the TE process framework in SMEs by using a quantitative research method and consequently considering a larger sample to achieve a higher generalizability.

Moreover, the completion of one more stage of data analysis in a future study through for example, conducting a focus group, quantitatively testing the developed framework, or conducting a case study would further increase the validity of our findings.

Another limitation is that the current state of research on TE activities in German SMEs is at a very early stage but is becoming immensely important. While we consider currently identified theoretical and empirical findings in our framework, future research could reasonably extend our research findings with additional insights that might emerge with further development of this phenomenon.

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