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Technological innovations of hidden champions: Evidence from patent data

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Abstract

The hidden champion concept has received much interest in practice. As market leaders in niche markets, hidden champions represent the success of the (German) Mittelstand. Innovation is a key element of their strategy and their focus and niche market strategy are associated with specific technological capabilities. However, thus far, little quantitative empirical evidence exists about the innovation output of hidden champions. Drawing on a capability perspective and using patent data, the present study analyzes differences between hidden champions and comparable non-hidden champion firms in their technological innovation. Our results show that hidden champions have a significantly larger technological innovation output but do not have a higher efficiency in their innovation creation compared to other firms from the same industry, size, and age. Moreover, the innovations produced by hidden champions show higher levels of technological depth and indicate lower levels of technological breadth. The sources of technological knowledge of hidden champions seem to be more inward oriented. Finally, innovations of hidden champions have similar technological impact, novelty and quality compared to those of other firms. Overall, our study supports many of the anecdotal beliefs about the innovation of hidden champions contributing to a better understanding of what makes hidden champions different from other Mittelstand firms. Practical implications for hidden champions and Mittelstand firms are discussed.

KEYWORDS

capabilities, hidden champions, Mittelstand, niche entrepreneurship, patents

1 | INTRODUCTION

The Mittelstand entrepreneurship innovation model has been described as an antithesis to the Silicon Valley model of entrepreneurship and innovation (De Massis

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et al., 2018; Pahnke & Welter, 2019). In particular, hidden champions are regarded as the prototype of successful, export-oriented, and technologically innovative Mittelstand firms (Audretsch et al., 2021; Johann et al., 2022). The hidden champion concept was pioneered by Simon (1992) and describes small and highly specialized (world) market leaders.[1] Innovation is described as a core element of the hidden champion concept and regarded as one of the main differences between hidden champions and other Mittelstand firms. However, thus far, little quantitative evidence exists on the particularities of innovation of hidden champions. Moreover, the literature is often based on more pragmatic explanations but lacks a theoretical perspective to explain the unique innovation characteristics of hidden champions with regard to technological innovation.

Our study aims to close these gaps and refine the innovation related assumptions that exist about innovation of hidden champions in the popular management literature. In particular, we aim to understand the differences in *technological* innovation outputs between hidden champions and other firms from the same industry and of similar size and age. Based on a capability perspective (Helfat & Winter, 2011), we identify three main capabilities of hidden champions that are associated with their technological innovation. Our research question is thus as follows: How do hidden champions differ from comparable other firms in their technological innovation outputs?

To analyze our research question, we use a panel dataset of 4677 firms with 25,475 patent applications from the German manufacturing sector. By using patent applications as a proxy for technological innovation, we find that hidden champions have significantly larger innovation outputs but are *not* more efficient in their innovation creation compared to other firms from the same industry, size, and age. Moreover, the innovations produced by hidden champions show higher levels of technological depth and lower levels of technological breadth. Innovation creation of hidden champions seems to be more inward oriented regarding sources of technological knowledge, and the resulting innovations show lower levels of novelty. Innovations of hidden champions have similar technological impact and quality compared to those of other firms.

Overall, our study supports many anecdotal beliefs about hidden champions and their innovation outputs. The article contributes to the small but growing literature on hidden champions and the hidden champion concept

Practitioner Points

- Managers should recognize the three key capabilities—niche marketing, internationalization, and integration—that drive hidden champions' technological innovation.
- Hidden champions generate more technological innovation output but without using fewer resources. Their innovations have greater technological depth, narrower breadth, and rely more on internal knowledge sources.
- Since hidden champions rely primarily on internal knowledge, managers could boost innovation by prioritizing external collaborations for new technical solutions.
- Given hidden champions' focus on technological depth and specialized innovations, caution is needed to prevent the risks of over-specialization.

(e.g., Audretsch et al., 2021; Benz et al., 2021; Johann et al., 2022; for a summary see Schenkenhofer, 2022) and helps to understand hidden champions' general approach toward innovation and technology, their innovation capabilities, and output. More precisely, it puts some of the propositions made by Hermann Simon in his pioneering and well-received books (Simon, 2009, 2022) to an empirical test. It also extends the conceptual work of De Massis et al. (2018), who refer to hidden champions as an example of how Mittelstand firms can innovate with limited resources. Hence, our study does not only evaluate whether hidden champions are innovative or not (which is a somewhat tautological question given the market leadership characteristic of hidden champions) but goes much deeper exploring the nature and characteristics of their innovativeness.

Furthermore, our study contributes to research on capabilities and their impact on innovation outputs. Based on three distinct capabilities of hidden champions (i.e., niche marketing capability, internationalization capability, and integrative capability), we present theoretical reasoning to explain how these specific capabilities, derived from a concentrated niche market strategy, impact the processes and results of technological innovation. The empirical analysis of hidden champion technological innovation outputs shows that contrary to dominant notions (Teece, 2007) even capabilities that integrate dynamic facets may create path dependencies (Sydow et al., 2009) and hinder more radical innovation. On a more general level, we thereby also contribute to the strategic management literature on niche market

[1]Simon (2022) defines them as firms that have revenues below $5 billion, are number one, two or three in the global market or number one on their continent and have a low level of public visibility.

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strategies (e.g., Teplensky et al., 1993; Toften & Hammervoll, 2009).

2 | BACKGROUND ON HIDDEN CHAMPIONS

2.1 | Concept and definition of hidden champions

Germany's postwar economic success is often associated with the development and success of its medium-sized manufacturing firms—the (industrial) Mittelstand. Hidden champions form a small but important and highly successful subgroup of the Mittelstand. The term "hidden champion" refers to market leadership in a narrow and specific niche market (mostly) unknown to the general public (Audretsch et al., 2021; Schenkenhofer, 2022). According to Porter' (1980) generic competitive strategies, firms can achieve a competitive advantage through (1) cost leadership, (2) product differentiation, or (3) focus. Hidden champions pursue a focus strategy, offering products specifically tailored to the needs of selected customers in narrowly defined niche markets, ranging from cinema curtains, pharmaceutical packaging, tunnel boring machines to church organs (Simon, 1992). As market leaders in niche markets (typically B2B), hidden champions do not target the "average" customer but rather seek to offer the best product for the most demanding customers with whom they work closely together (Massis et al., 2018; Simon, 2022). Moreover, hidden champions have historically neither attracted nor sought publicity (Simon, 2009), explaining why they are *hidden*. Even though they have their roots in the German context, hidden champions are not only a German phenomenon. Research has identified and analyzed hidden champions all over the world, including Greece (Voudouris et al., 2000), Turkey (Yosun & Cetindamar, 2013), Korea (Kim & Kim, 2015), Britain (Witt, 2015), and Croatia (Omazic & Vlahov, 2013).

The hidden champion concept has its roots in the 1990s and the works of Hermann Simon (Simon, 1992, 2009, 2022). In line with Simon (2022), we define hidden champions using two main criteria. (1) *Market leadership*: hidden champions should be among the top three market-leading firms in the world or rank first on their continent. Simon concludes that it is sometimes difficult to determine the exact market share of a firm as this share depends on the particular market definition and market delineation used. He also states that, beyond market share, more subjective criteria, such as quality leadership, can be used to assess market leadership. Such subjective criteria can but do not have to include the innovativeness of a firm. (2) *Firm size*: hidden champions have revenues of less than five billion Euros.[2]

2.2 | A capability-based view of the characteristics of hidden champions

Innovation in general is considered a crucial characteristic of hidden champions (Simon, 2022; Voudouris et al., 2000). As hidden champions rely on competitive advantages created by offering high-quality products specifically tailored to the needs of selected customers in narrowly defined niche markets, innovation is important for the long-term success and survival. Hidden champions aim to be technologically superior and offer higher product quality than competitors to justify their price premiums (Audretsch et al., 2021; Johann et al., 2022; Rammer & Spielkamp, 2019; Simon, 2022). They produce technologically sophisticated and knowledge-intense products, which also creates a strong need for intellectual property (IP) protection through patents and other IP rights (Schenkenhofer, 2022). Besides this general observation in the literature, there is little evidence on the nature of technological innovation in hidden champions. Our study aims to reduce this gap.

As a theoretical basis to understand the nature of technological innovation of hidden champions, we take an organizational capability perspective. Organizational capabilities refer to the collective skills, competencies, and resources utilized in an organization's processes to create and sustain a competitive advantage in a specific industry or market (Amit & Schoemaker, 1993). These capabilities are directed and limited to specific purposes (e.g., new product introductions) but can be repeated across single-use cases (Helfat & Winter, 2011). Thus, firms that have the capability to develop and introduce new products because of their specific R&D and marketing resources (e.g., human capital, technologies, knowledge) and processes can repeatedly utilize these capabilities for multiple new products. Capabilities allow firms to effectively utilize their resources and deliver value to customers in a way that is difficult for competitors to imitate and replicate (Helfat & Winter, 2011). Organizational capabilities comprise ordinary as well as dynamic elements. *Ordinary capabilities* allow a firm to "perform an activity on an on-going basis using more or less the same techniques on the same scale to support

[2]Simon (2022) adds low public visibility as a third criterion to the operational definition. As this criterion, however, subjectively varies across stakeholders, he does not operationalize this criterion. Therefore, this criterion is typically not included in the operational definition of hidden champions (e.g., Rammer & Spielkamp, 2015).

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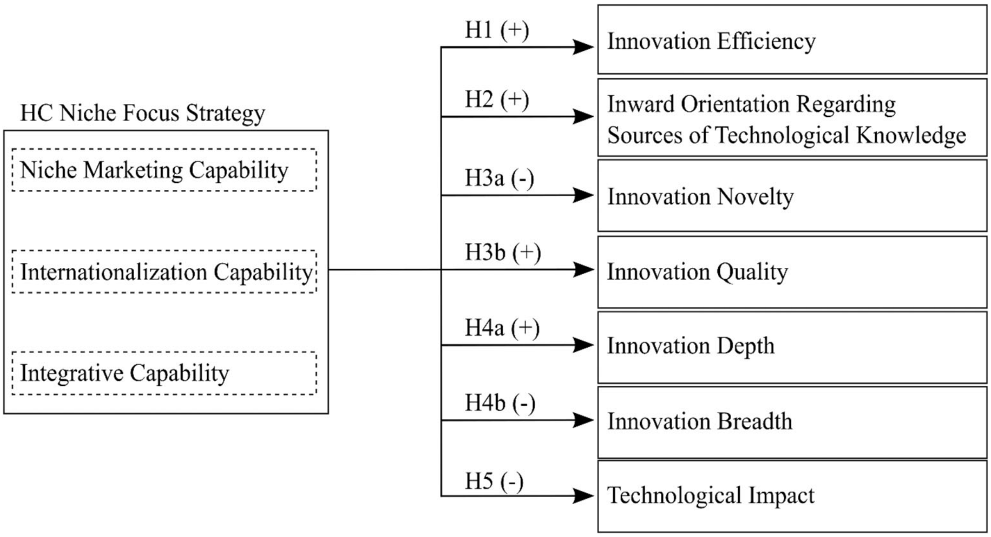

FIGURE 1 Theoretical framework of hidden champion capabilities and technological innovation.

existing products and services for the same customer population" (Helfat & Winter, 2011, p. 1244). These ordinary capabilities are necessary to maintain the efficiency of operations related to existing products and services (Teece, 2017). Therefore, ordinary capabilities are rather static in nature (Barreto, 2010). *Dynamic capabilities*, in contrast, "help enable an enterprise to profitably build and renew resources, reconfiguring them as needed to innovate and respond to (or bring about) changes in the market and in the business environment more generally" (Teece, 2017, p. 698). Therefore, dynamic capabilities always involve altering ordinary capabilities (Winter, 2003) and facilitating organizational change, although not necessarily in a radical way (Helfat & Winter, 2011).

Based on the capability perspective, we argue that the characteristics of hidden champions constitute particular capabilities, which in turn affect their technological innovation outputs (see Figure 1). Prior research has described hidden champions through their niche market focus with a high customer orientation in a specific field, their strong international orientation mirrored in a high percentage of exports and high foreign direct investments, and their high vertical integration to manage and control large parts of their production process and value chain (Audretsch et al., 2018; Dalgic & Leeuw, 1994; Rammer & Spielkamp, 2015; Simon, 2022; Voudouris et al., 2000). Following previous research on the development of organizational capabilities (Sharma & Vredenburg, 1998), such clear strategic focus areas lead to the development of specific capabilities of hidden champions that are deeply embedded in an organization, including its routines, organizational frameworks, communication channels and problem-solving strategies (Daft & Weick, 1984; Henderson & Clark, 1990). This is because strategic choices determine organizational governance systems and structures and interrelated investments in physical, human, and other intangible assets, leading to capability development (Argyres, 2011; Argyres & Liebeskind, 2002; Schriber & Löwstedt, 2015). Contrasting the above characteristics of hidden champions with the established organizational capability literature, we identified three main organizational capabilities of hidden champions and adapted these to the particularities of hidden champions: (1) *Niche marketing capability*, (2) *internationalization capability*, and (3) *integration capability*. In the following we argue why each of these three organizational capabilities matches the characteristics of hidden champions.

Adapted from Day (2011), we define the *niche marketing capability* of hidden champions as the ability to create and deliver superior customer value through efficient and fast-responding marketing processes for well defined (niche) markets.[3] This capability comprises activities related to maintaining the sustainable market positioning of established products and those directed at establishing new products (Helfat & Winter, 2011). In line with the particularities of hidden champions (Rammer & Spielkamp, 2015; Simon, 2022), this capability is particularly based on a strong market and customer orientation that enables the hidden champion to sense market developments continuously and to better align its resources with market demands and specific customer needs as compared to competitors (Day, 2011; Fang & Zou, 2009;

[3]Day (2011) does only refer to marketing capabilities. Considering the niche focus of hidden champions, we specified this capability to a niche marketing capability for hidden champions.

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Morgan et al., 2009). Based on hidden champions in Greece, Voudouris et al. (2000) empirically substantiate that a close commitment to customer service is a key success factor of hidden champions. Their deep market insights as well as strong and close connections to important (B2B) customers create strategic capabilities that facilitate hidden champions to be a customer value leader through their distinct and compelling customer value proposition and to respond to new demands in their established markets with new value propositions (Day & Moorman, 2010). Firms with such strategic marketing capabilities "stand out in their ability to continuously sense and act on emerging trends and events in their markets" (Day, 2011, p. 186). The example of the hidden champion Rose Plastic illustrates the existence of these capabilities in hidden champions. The firm describes itself as "the world's No. 1 supplier of high-quality hard plastic packaging for the tooling industry." Their strong focus on the tooling industry allows them to come up with high-quality, highly customized, and highly innovative solutions. The long-term and intensive collaboration with important customers puts them in a good position to understand the needs of their customers, to continuously react to new demands and maintain their strong competitive position.

The *internationalization capability* of hidden champions is the ability to identify, evaluate, and (successfully) exploit opportunities that arise in foreign markets (Bingham et al., 2019; Catanzaro & Teyssier, 2021). Internationalization requires overcoming significant obstacles, including the challenges posed by cultural disparities, geographical distance from key markets, variations in financial and economic structures, and rigidity of the enterprise to adapt and learn (Raymond et al., 2014). This capability comprises several sub-dimensions that are required to successfully maintain and manage export relationships and foreign subsidiaries (i.e., international exploitation) as well as the extension of the current business to new international markets (international exploration) (Pinho & Prange, 2016; Prange & Verdier, 2011). Research shows that internationalization capabilities are developed through repeated experiences in internationalization that create routines (Sapienza et al., 2006), knowledge (Eriksson et al., 1997), and heuristics (i.e., boundary rules and how-to rules) (Bingham et al., 2019). To overcome the small size of the niche markets in their home region, hidden champions have to rely heavily on internationalization (Dalgic & Leeuw, 1994) and quickly expand their activities on a global scale, which explains their international success and high export shares.

Because of their high export shares and strong international orientation, hidden champions can draw on substantial experiences in both international exploitation and exploration that shape their internationalization capabilities. Audretsch et al. (2018) have investigated the particularities of hidden champions with regard to internationalization. As hidden champions typically produce products of premium quality that require considerable explanation and service, they want to maintain control and enter foreign markets often through equity modes of market entry such as wholly owned subsidiaries. Consequently, this intense direct engagement in international markets substantially fosters the development of internationalization capabilities. A consequent internationalization puts hidden champions in a good position to observe customers in different contexts and environments, which is a fruitful source for innovation ideas (Gertler, 1995; Malecki, 2010). Many hidden champions are, for example, located in the city of Taicang, which is a German hub of Mittelstand firms active in China. The German hidden champions located in China, increasingly not only distribute and/or produce their products in China but also source innovation ideas from China, which is becoming the largest market in some industries. In a similar vein, the above described hidden champion Rose Plastic has cleanrooms both located at their headquarters in Germany and in the US. The latter is the largest pharmaceutical market of the world, which is a challenging but highly profitable industry, where Rose Plastic is diversifying into.[4]

The *integrative capability* of hidden champions refers to their ability to effectively coordinate and control communication, key activities, investments, and objectives across different stages of the value chain (Helfat & Campo-Rembado, 2016; Iansiti & Clark, 1994). Integrative capabilities facilitate the seamless coordination of value creation activities under different circumstances. In times of little or no change, integrative capabilities enable greater control over the manufacturing process and the quality of products. However, if changes are required or new products are introduced, rapid adaptation of these integrated systems is possible (Helfat & Campo-Rembado, 2016; Li, 2005). We argue that to serve their highly demanding customers with high quality and customized products, hidden champions need to develop integrative capabilities often resulting from a high degree of vertical integration across the value chain. Hidden champions are particularly skeptical about giving up control and independence (De Massis et al., 2018). As niche specialists focusing on high quality products, they want to preserve control over the key activities in each step of the value creation and value chain (Rammer & Spielkamp, 2015; Schenkenhofer, 2022; Simon, 2022). This ambition also mirrors in hidden champions strong

[4]See https://www.rose-medipack.us/en (accessed July 9, 2023).

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and holistic leadership together with keeping responsibility and decision-making authority in the larger organization (Voudouris et al., 2000). In streamlining their value chains, they develop substantial skills in carrying out each value creation step and a high degree of specificity between the integrated steps of the value chain, intensifying the degree of vertical integration (Argyres, 1996; Díez-Vial, 2007). Consequent investment in and alignment of resources along the value chain strengthen the development of integrative capabilities. Many hidden champions, for example, have their own machine shops and mechanical engineering departments to repair, adapt, and produce their own machines used in the production. Examples of such hidden champions are Brita,[5] the market leader in countertop water filters, and the Bauer AG,[6] a leading specialist foundation engineering company. Based on these three specific capabilities of hidden champion, we now develop hypotheses about technological innovation outputs of hidden champions. Figure 1 links our capability-based view of hidden champions with the hypotheses.

3 | HYPOTHESES ABOUT TECHNOLOGICAL INNOVATION OUTPUTS OF HIDDEN CHAMPIONS

We use the above-developed theoretical considerations about the specific capabilities of hidden champions to hypothesize their particularities regarding technological innovation outputs compared to other non-hidden champion Mittelstand firms.

3.1 | Innovation efficiency

We refer to innovation efficiency as the quantity of innovation output in relation to the resources that a firm employs to achieve this output. We argue that the specific capabilities of hidden champions foster their innovation efficiency. The close customer interaction and strong customer orientation embedded in their *niche marketing capability* enables them to sense market developments quickly and to continuously align resources with new or adjusted market demands (Day, 2011; Fang & Zou, 2009; Morgan et al., 2009). According to the literature on the sources of innovation, close collaboration with customers and careful observation of their needs is a fruitful source of ideas for innovation (Abrell et al., 2016; Bonner & Walker Jr, 2004). Thus, hidden champions avoid unnecessary circumventions of extensive market search for ideas of innovation and highly risky and explorative research but instead focus their innovation efforts on activities likely to yield predictable innovation output and successful market results. Repeated new product initiations in their respective niche market have created capabilities to bring new technologies and products to the market efficiently (Helfat & Winter, 2011).

Furthermore, hidden champion's *integrative capability* facilitates control over the most relevant parts of the value chain. Therefore, hidden champions have substantial independence from external actors, and new market demands can be addressed to a significant degree by utilizing internal resources and processes. Consequently, inefficiencies and transaction costs related to vertical disintegration are reduced. If adaptation or innovation of products and/or processes is needed, rapid adaptation of hidden champions' integrated value chains is possible (Helfat & Campo-Rembado, 2016; Li, 2005). In line with this, Simon (2022) and De Massis et al. (2018) have already argued that hidden champions are particularly efficient in their innovation processes.

The hidden champion **Uhlmann** located in Laupheim provides a good case in point for this argument. They are the leading system supplier for pharmaceutical packaging. Their only customers are "international pharmaceutical groups, generic manufacturers, and packaging service providers,"[7] for which they are a total solution provider offering everything from a single source. Hence, they devote their entire innovation activities toward satisfying the varying demands of this narrow, yet highly demanding group of customers based on resources and processes under their control.

Following the above arguments, hidden champions should be more efficient in their innovation activities, producing more innovations per employee than other firms of similar size and age.

> **Hypothesis H1:.** Hidden champions have a higher innovation efficiency than other firms.

3.2 | Inward orientation regarding sources of technological knowledge

A firm's inward orientation regarding sources of technological knowledge captures the degree to which the technological knowledge for an innovative problem solution comes from internal rather than external knowledge sources. While hidden champions have a strong market

[5]See https://www.brita.de (accessed March 18, 2024).
[6]See https://www.bauer.de (accessed March 18, 2024).
[7]See https://www.uhlmann.de/company/profile-and-organization (accessed July 9, 2023).

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orientation regarding the ideas for innovation (see hypothesis above), we argue that they are rather inward oriented regarding the sources of technological knowledge needed for creating the technical solutions. External innovation cooperation partners such as customers primarily take the role of idea givers for identifying unmet market demands (e.g., West & Bogers, 2014). They do not provide the technological knowledge needed to develop the technological solutions created to meet these demands.

We shall argue that hidden champion's *integrative capability* and the related benefits for innovation efficiency mentioned above will lead to a stronger inward orientation of hidden champions regarding sources of technological knowledge for technological innovation than this is the case in comparable firms. Hidden champions integrative capability is closely associated with their skepticism about giving up control and independence. This also applies to the sources of technological knowledge. Hidden champions want to maintain control over their sources of knowledge (De Massis et al., 2018) and do not want to become dependent on external sources of knowledge and knowledge providers. Besides the control argument, Helfat and Campo-Rembado (2016) show that integrative capabilities are beneficial for systemic innovation that requires embedded integrative knowledge about how to systematically integrate different activities, capabilities, and products along the value chain. Sourcing on internal knowledge therefore ensures systemic compatibility of components and technologies. In a similar vein, Kapoor (2013) argues that specialized continuous innovation (e.g., to adapt to regular demands of customers) often builds on pre-existing knowledge embedded in an integrated value chain. Helfat and Campo-Rembado (2016) even buttress that firms who built integrative capabilities intentionally disregard the potential benefits of disintegration and external knowledge sourcing.

A good example is the Wipotec Group from Kaiserslautern, which describes itself as a "leading global provider of intelligent weighing and inspection technology."[8] Similar to the example of the hidden champion Uhlheim discussed in Hypothesis 1, the firm is proud that their "integrated solutions come from 'a single source' and extend along the entire value creation chain from hardware and software development to in-house production with a level of vertical integration exceeding 85% and after-sales service."[9] Although this single source for their solutions assumingly enhances the efficiency and facilitates systemic integration of solutions, the underlying integrative capability will also constrain hidden champions in external cooperation and knowledge sourcing beyond resources under their control. In this case, the integrative capability can become a liability, forcing hidden champions to rely on knowledge sources under their control and making hidden champions skeptical about open innovation and innovation collaboration (Tushman et al., 2012). They will not only avoid sharing their own knowledge with other firms or institutions, but they are also skeptical about insourcing technological knowledge from outside sources beyond their control. Consequently, hidden champions primarily rely on their established internal solution spaces and past technologies when creating new products. We hypothesize:

> **Hypothesis H2:.** Hidden champions have a higher inward orientation regarding sources of technological knowledge than other firms.

3.3 | Innovation novelty and quality

A strong inward orientation regarding sources of technological knowledge often goes hand in hand with a low degree of *innovation novelty*.

We define a novel innovation as one that has no or little "discernible technological antecedents" (Ahuja & Lampert, 2001, p. 535). The innovation is among the first ones of its kind from a technological perspective.[10] Novelty, particularly that of technological innovations, has been widely understood as a focal aspect of knowledge creation (Kaplan & Vakili, 2015; Uzzi et al., 2013). Novel innovations with characteristics substantially differing from previous innovations have also been framed as (technologically) radical (Schoenmakers & Duysters, 2010)—the opposite being incremental. These radical innovations can change technological paradigms (Nelson & Winter, 1982), creating entirely new technological fields and industries. However, radical innovations also present a risky departure from existing practice (Hage, 1980). In contrast, less novel or incremental innovations consist of minor improvements in existing technologies.

[8]See https://www.wipotec.com/en/company/about-us (accessed July 9, 2023).

[9]See https://www.wipotec.com/en/company/about-us (accessed July 9, 2023).

[10]Note that also other perspectives on innovation novelty exist. Verhoeven (2016), for example, distinguish between novelty in recombination and novelty in knowledge origin. While the latter resembles to what we refer to as inward orientation regarding sources of technological knowledge, the former describes the extent to which it "recombines components and principles to serve its purpose" (Verhoeven et al., 2016, p. 708).

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We argue that hidden champions, because of their *niche marketing* and *internationalization capabilities*, tend to pursue technological improvements and, thus, incremental innovations instead of radical ones. A core aspect of their niche marketing capability is a close interaction with a narrow set of customers in their niche market. Therefore, hidden champions can quickly respond to new market demands with new problem solutions (Day, 2011). Thereby, they increase customer loyalty, satisfy the needs of their lead customers, and safeguard technology leadership (Riisalu & Leppiman, 2013; Voudouris et al., 2000). This capability will likely continuously increase incremental innovation but may not be favorable for more radical innovation beyond the existing technological scope and the customers' expectations. Hidden champions do not want to disrupt their own markets via new technologies but rather seek to maintain and protect their market leadership through incremental innovations related to their existing product and knowledge spaces. Previous research has found that established market leaders often innovate incrementally (Christensen, 1997) and produce less novel technological innovations. This effect will be intensified through hidden champion's *internationalization capability*, which is directed to exploit the international market share in established markets, primarily through wholly owned subsidiaries (Audretsch et al., 2018). Whereas this capability is helpful for an international expansion with incremental innovation, it may even create rigidity regarding radical innovation that is less compatible with a fully controlled international sales and distribution system.

By relying on core concepts manifested in their technological spaces, hidden champions are thus likely to rely mostly on recombining (their own) existing knowledge rather than creating entirely new knowledge. We hypothesize the following:

> **Hypothesis H3a:.** Hidden champions produce innovations of lower technological novelty than other firms.

On the contrary, the lower focus on novelty allows hidden champions to dedicate their resources and capabilities to create innovations of higher quality. *Innovation quality* is a multidimensional concept that comprises various aspects of innovation excellence and effectiveness. The literature has come up with a wide range of conceptualizations overlapping to some extent with our understanding of novelty (H3a) and technological impact (H5). Higham et al. (2021) provide a comprehensive overview. In our study, we refer to a particular aspect of innovation quality. This aspect is often referred to as one of the characteristics of success of hidden champions and concerns the functional efficiency and operability of the innovation. That is, the innovation provides a well-functioning and rigorous solution for a relevant technical problem. But why are hidden champions able to produce such well-functioning and highly operable innovations?

Hidden champion's *niche marketing capability* can be considered a driver of innovation quality in the sense as described above. Hidden champions close interactions with their established customers facilitates that real and important customer problems are identified and fully understood before innovation concepts are realized. This interaction may continue from the initial idea phase over the concept development to the market entry of a new product. Consequently, the niche marketing capability reduces the likelihood that solutions and concepts of low innovation quality are created. Such high innovation quality is also needed from a market perspective, as hidden champions aim for high standards in product quality and cannot afford to produce low-quality innovations that do not work. Besides that, as this capability is directed to narrow niche markets and a limited technological domain, hidden champions have a detailed understanding of technologies and potential solutions. This further reduces the risk that innovation by hidden champions fails due to technical and/or market demand-related reasons.

Next to their niche marketing capability also their *integrative capability* helps hidden champions to develop innovations of high quality. By being in control of the value chain and the different elements of the innovation process, hidden champions are in a good position to develop innovations of high quality and technical standards.

Based on hidden champions niche marketing and integrative capabilities, we expect them to produce innovations of high technological quality. We formulate the following hypothesis:

> **Hypothesis H3b:.** Hidden champions produce innovations of higher technological quality than other firms.

3.4 | Innovation depth and breadth

Prior research has stressed the importance of distinguishing between the breadth and depth of a firm's technological innovation portfolio (Aharonson & Schilling, 2016; Xu, 2015; Zhou & Li, 2012). *Breadth* is defined as the range of technological fields in which a firm is represented, and *depth* refers to the amount of technological knowledge within a technological field (Laursen & Salter, 2006; Xu, 2015).

We argue that all three specific capabilities of hidden champions are associated with a greater innovation depth but reduced innovation breadth as compared to other firms. First and foremost, hidden champion's *integrative capability*

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fosters innovation depth. The ability to control the product and knowledge flows along the value chain leads to a significant concentration of knowledge in one narrow knowledge domain. In contrast, the breadth of technological knowledge will be naturally reduced as the integrative capability minimizes the reliance on heterogeneous actors (e.g., relatively unknown suppliers) that can provide access to broad and diverse knowledge domains (e.g., Palit et al., 2022). An example of such a vertically integrated specialist is the above mentioned hidden champion Bauer AG and the associated Bauer Maschinen GmbH from the city of Schrobenhausen in Bavaria. They develop and manufacture their own construction machines to perform their challenging construction jobs as a specialist foundation engineering company.[11] For hidden champions, technological depth is key and becoming overly broad in technological fields and applications would distract and destroy the benefits of (technological) specialization and focus. In a similar vein, the nature of hidden champion's *internationalization capability* will be associated with a high innovation depth. Internationalization of hidden champions follows the aim to extend the market size often associated with creating own subsidies in foreign markets (Audretsch et al., 2018). The internationalization capability and the direct involvement of hidden champions in foreign markets will thus provide access to country-specific knowledge in the particular knowledge domain of the hidden champions niche market. Lastly, the *niche marketing capability* puts hidden champions in close contact with customers, providing them access to important customer knowledge. However, this close customer orientation to the most demanding customers puts hidden champions in a position where they have little incentive to change technology and incur the costs associated with adopting new technology reducing innovation breadth. Hence, the niche market capability can also become a liability. To maintain their position, hidden champions build on their prior knowledge as the state-of-the-art knowledge base in their technological niches. Tripsas (1997) shows that firms often utilize specialized assets to maintain market leadership.

Taken together, we assume that the particular capabilities of hidden champions will, on the one hand, help to utilize access to domain-specific knowledge and lead to greater innovation depth. On the other hand, they will reduce the breadth of innovation (activities) compared to other firms.

> **Hypothesis H4a:.** Hidden champions have a higher innovation depth than other firms.

> **Hypothesis H4b:.** Hidden champions have a lower innovation breadth than other firms.

[11]See https://www.bauer.de (accessed March 18, 2023) and Block et al. (2016), where this example is described in great detail.

3.5 | Technological impact

Our last hypothesis concerns the technological impact of innovations produced by hidden champions. The technological impact of an innovation refers to how much a specific innovation builds the fundament of (future) innovations and technologies created by others and shapes the development of entire technological fields (Dahlin & Behrens, 2005; Hopp et al., 2018).

In line with our arguments regarding innovation breadth, we assume that the capabilities of hidden champions may not be optimally suited to create high technological impact innovations. The *integrative capability* and the strong desire to maintain control limits their potential to develop innovations of high technological impact. Prior research shows that innovations with high technological impact are often created at the intersections of different technological fields and actors (Rosenkopf & Almeida, 2003; Rosenkopf & Nerkar, 2001). However, as hidden champions focus primarily on those technological domains captured by their internal competencies and value chains, technological knowledge diversity as a basis for potential knowledge spillovers in other applications, industries, and markets is naturally limited. Also, the *niche marketing capability* of hidden champions may not be helpful to create technological innovations of high technological impact. By focusing almost exclusively on the demands of their current customers and by striving to stay market leader in their niche markets, hidden champions may overlook important technological developments that have the potential to impact different industries and markets.

Following the arguments around hidden champion's integrative and niche marketing capabilities, we posit:

> **Hypothesis H5:.** Hidden champions produce innovations with lower technological impact than other firms.

4 | DATA AND METHODS

4.1 | Data sources and construction of estimation dataset

Our study builds on a self-constructed dataset of German manufacturing Mittelstand firms derived from two data sources covering the years 2011–2019: (1) firm-level data from the Orbis database and (2) patent-level data from PATSTAT.[12]

We started by constructing a dataset of German manufacturing Mittelstand firms from the Orbis database

[12]We used PATSTAT Global—2022 Autumn Edition.

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that matched the following inclusion criteria. The firm should be for-profit, active (as of December 2020) and independent—not a subsidiary or foreign firm. It should have between 50 and 2999 employees and revenues below five billion Euros (in the year 2018). Moreover, it should be a manufacturing firm; that is, its primary NACE code should be between 10 and 33. The result was a dataset of 9594 German manufacturing Mittelstand firms. Note that we use a quantitative Mittelstand definition based on the number of firm employees.

In a next step, we collected patent information for these firms. Patent data were retrieved from the PATSTAT database provided by the European Patent Office (De Rassenfosse et al., 2014). We focused on patent applications in Germany and identified 51,733 patent applications for the 9594 sample firms from 2011 to 2019. To match patent applications with their corresponding firms, we followed the seven-step approach proposed by Willeke et al. (2023). In essence, this process targets at matching firms and patent applicants (i.e., persons or firms applying for the patent) primarily based on the names and addresses provided by PATSTAT. When no patent application could be identified, the patent application variable was coded as zero. We then had to eliminate many firm-year observations that had missing values for some control variables (e.g., return on assets), which resulted in an estimation dataset of 41,217 firm-year observations from 4677 firms spanning the years from 2011 to 2019.[13]

4.2 | Dependent variables

To test our hypotheses and research questions, we built eight dependent variables representing our overarching constructs.

4.2.1 | Innovation efficiency and quantity

First—to enable additional insights exceeding this study's hypothesized effects, we measured innovation quantity, calculating the logarithm of the number of patent applications per firm and year. This approach is in line with previous research that argues that hidden champions' higher innovation output is the result of being more productive (Rammer & Spielkamp, 2015). Second, we calculated an efficiency measure (Lanjouw & Schankerman, 2004) by dividing the number of a firm's patent applications by the number of employees for each year. For firms with missing employee data in a specific year, we used the respective firm's average number of employees across the years covered by our dataset.

4.2.2 | Inward orientation regarding sources of technological knowledge

We measured inward orientation regarding sources of technological knowledge with counting self-citations, that is, backward citations given to own patents (Hall et al., 2005). A higher number of self-citations indicate a higher degree of incremental and follow-on innovation (Moser et al., 2018). Again, we normalized this quantity by the number of a firm's patent applications in the respective year.

4.2.3 | Innovation novelty and quality

For creating the innovation novelty measure, we followed previous research and counted the number of backward citations of all patent applications per firm and year (Ahuja & Lampert, 2001; Schoenmakers & Duysters, 2010). We further divided that quantity by the overall number of patent applications of each firm and year. This measure reflects the rationale that a higher number of backward citations should indicate a higher degree of prior art and, thus, lower novelty of the respective invention (Gerken & Moehrle, 2012; Rost, 2010). Analogously, a low number of backward citations indicates less reference to prior inventions and, thus, higher novelty. To interpret a high quantity of our measure as a high degree of novelty, we multiplied the quantity by minus one. The innovation quality was measured, following previous research by using the ratio of granted patents to patent applications for each firm and year (Ernst, 1995; Griliches, 1990; Lampe, 2023). A high patent grant ratio indicates that a firm submits high quality well-prepared patent applications likely to meet the patentability requirements.

4.2.4 | Innovation depth and breadth

Our measures of innovation breadth and depth relied on differences in the technology classes that were addressed by the firms' patent applications. Our measurement

[13]The drop in observations is due to the number of missing information fields for the two control variables (i) return on assets and (ii) debt-to-equity ratio. We used mean imputation to address missing values (see a more detailed explanation in the subsection focusing on the control variables). However, for several firms no information was given at all (for return on assets and debt-to-equity ratio) preventing mean imputation. This led to a drop from over 9,000 to 4,677 firms. The number of patents for the 4,677 firms was 25,475 patents.

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approach builds upon Schmoch's (2008) criticism on traditional overlapping and broad classes (e.g., the IPC classes) and his proposal to categorize patent applications into 35 more distinct *technology fields*. The adoption of the technology field concept is pervasive in recent studies (Ceipek et al., 2021; Pintar & Scherngell, 2022). To do so, we combined approaches from Boh et al. (2014) and Laursen and Salter (2006). Technological innovation breadth reflects a firm's *relative* diverse technological expertise (Fleming et al., 2007). In this regard, we counted the number of technology fields to which a firm's patent applications belonged in a certain year. As an example, five patent applications in our different technology fields resulted in a count of four. Dividing this count by the number of inventions of a firm-year observation, thus, resulted in a breadth value of 0.8. It should be noted that this procedure deliberately resulted in a measure that is conceptually and empirically distinct from the overall output. As a further example, a firm with 10 patent applications in four different technology classes would gather a count of 0.4 despite the overall higher innovation output.

In contrast, innovation depth indicates the knowledge level in a core technological area and, thus, specifies the reuse of knowledge (Katila & Ahuja, 2002). Following Laursen and Salter (2006), we measured depth as the repeated occurrences of technology fields in a firm's list of patent applications. When a technology field occurred more than three times in a firm's patent applications in a year, these were counted. Again, this measure was then divided by the number of patent applications per firm-year observation. Similar to our rationale for the breadth measure, the relative depth, namely a firm's relative focus is in the foreground here.

4.2.5 | Technological impact

For measuring technological impact, we calculated the ratio of the number of forward citations per year (Hall et al., 2005; Singh & Fleming, 2010; Trajtenberg, 1990) to the number of patent applications by that firm in that year.

4.3 | Independent and control variables

4.3.1 | The hidden champion variable

The independent variable hidden champion was a dummy variable representing whether the firm was a hidden champion (coded as 1) or not (coded as 0). The coding of this variable was based on the market leadership criterion created by Simon (2022), that is, the respective firm was among the top three market leaders in the world or the market leader in Europe. To detect such firms in our dataset of German manufacturing Mittelstand firms, we followed Johann et al. (2022), Simon (2022) and others (Audretsch et al., 2018, 2021) and manually screened information from various sources over a long time period. That is, we constructed over a period of several years a list of potential world market leaders from media mentions, personal observations, interviews, and available world market leader rankings (e.g., WirtschaftsWoche, 2020). Next to this constant effort spanning several years, we searched actively for hidden champions around the time of the construction of the manuscript using hidden champion-related word strings in Google alerts, popular media, and press statements.[14] In addition, we gathered information from several available lists and news outlets to identify hidden champions (Langenscheidt & Venohr, 2014; Seibold et al., 2019; WirtschaftsWoche, 2020; Yogeshwar, 2019; Zeitung, 2019). As a final quality check, we went on each website of the potential hidden champion candidate and searched there actively for information about their market leadership. When a hidden champion ceased to exist or was acquired by another firm after that date, we still include this firm in our list as our data sample covers only the time period from 2011 to 2019. As a final step, we followed Simons' (2022) suggestion to check the visibility of the identified firms. With the help of five experts, we manually evaluated the public visibility of each of the hidden champion candidates in our dataset. Table A1 in the online appendix[15] contains the final results and shows the names and locations of the hidden champions that we identified. A total of 865 of the 9594 firms in our original Mittelstand dataset were hidden champions. Note that by construction our hidden champion variable is time-invariant and does not change over our sample period. Thus, fixed effects models or a comparison between random effects models and fixed effects models was not applicable.

An example of such a hidden champion is Spinner GmbH, a firm headquartered in Munich. With a global presence in the high-frequency technology niche sector and approximately 1000 employees, Spinner GmbH has positioned itself as a market leader in RF technology products. Another example is the firm SUSPA GmbH located in Altdorf. With around 1900 employees, the firm

[14] As our study focused on a German sample of firms, we used the German translation of the term "world market leader," namely, "Weltmarktführer." The term "Hidden Champion" is widespread in Germany and, thus, we used also its English form.

[15] The supplementary material can be accessed at https://osf.io/eywk9/.

is world market leader in the niche sector of washing machine dampers and adjustable hydraulic dampers. By being a market leader and exporting its products worldwide, the firm can be considered a hidden champion.

4.3.2 | Control variables

Our selection of control variables was based on the literature on the drivers of firm success and innovation (e.g., Andres, 2008; Miller et al., 2007; Werner et al., 2018). The control variables were extracted from Orbis on a yearly basis. We used *firm age* and *firm size* as control variables. Firm size was measured through the number of employees and we employed firm based mean imputation to address missing values in a particular year.[16] Both measures were inserted into the regression analyses as natural logarithms to account for potential nonlinear effects. Additionally, we controlled for a firm's industry by including two-digit *NACE dummies* as well as their location by including *federal state dummies*. Furthermore, ownership effects were taken into consideration by using a *blockholder dummy* variable to indicate shareholders owning more than 50% of a firm. To account for firm success, we controlled for the firm's performance using *return on assets*. The impact of capital structure was controlled by incorporating the yearly *debt-to-equity* ratio of the firm. Mean imputation was employed when information in specific years was missing. *Year dummies* were also included to address yearly effects. Lastly, to capture the influence of different technologies, we included *technology dummies* (in models focusing on firm-year observations where patents were applied—Table 3) derived from patent applications per year and aggregated for firm-year observations, using the PATSTAT patent database. The variable was derived from the technology field concept introduced by Schmoch (2008).

4.4 | Analytical procedure

To test our hypotheses, we estimated random effects panel data models. To test for unobserved panel-level heterogeneity we used the Breusch-Pagan test. The results indicated that heteroscedasticity exists (*p*-values were smaller than 0.05 in all model specifications), which led us to use White's heteroscedastic robust standard errors (at the firm level) in all model specifications.

For our second set of regression analyses, testing Hypotheses H2–H5, we considered only firm-year observations having at least one patent application. To apply for a patent is likely to be nonrandom, with several selection processes at work. As causes of such selections may influence the amount of patent applications, that is, there is potential for selection biases of estimation results (Certo et al., 2016). As a remedy, we applied Heckman (1979) proposed procedure and incorporated parameter estimates from a probit model based on information that represents all the firms-year observations into a second OLS model of interest (Certo et al., 2016).

5 | RESULTS

Table 1 presents descriptive statistics (means, standard deviations, and correlations) of our model variables.[17] The NACE distribution of the firms showed no abnormalities.[18] Notably, there were only modest correlations between the independent and control variables, indicating a low risk of multicollinearity.

5.1 | Tests of hypotheses

Table 2 presents the results of the random effects panel regression relevant for evaluating Hypotheses 1, which proposes higher innovation efficiency for hidden champions. Even though, to some extent tautological, we test the assumption that hidden champions have a higher innovation quantity. Model 1 contained the *number of patent applications* as a measure of quantitative innovation output and shows a positive significant effect ($\beta = 0.294$, $p < 0.01$). Model 2 contained the number of *patent applications per employee* as a measure for innovation efficiency. The effect was not significant ($\beta = 0.009$, $p > 0.1$), leading to no support for H1.

Table 3 presents the results of the models testing Hypotheses 2–5 which proposed that innovations conducted by hidden champions have a higher innovation efficiency (H1), inward orientation regarding sources of technological knowledge (H2), lower novelty (H3a), higher quality (H3b), higher depth (H4a), lower breadth (H4b), and lower technological impact (H5). It should be

[16]Firm size in the year 2018 was a selection criterion to construct our estimation sample. However, for some firms, earlier years in the Orbis database were missing. To not loose these observations from our sample, we mean imputed the firm size variable for the missing years.

[17]To conserve space, the descriptive statistics for federal state, NACE, year, and technology field dummies are not reported.

[18]Two-digit NACE industries (number of firms): 10(971), 11(140), 12(13), 13(179), 14(78), 15(39), 16(214), 17(258), 18(239), 19(26), 20(469), 21(164), 22(715), 23(390), 24(353), 25(1505), 26(670), 27(519), 28(1629), 29(263), 30(107), 31(156), 32(333), 33(151).

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TABLE 1 Descriptive statistics and correlation matrix.

	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Patent applications per employee	0.003	0.301												
(2) Self-citations per patent applications	0.579	1.115	0.009											
(3) Backward citations per patent applications	−6.191	5.412	0.000	−0.309**										
(4) Granted patents per patent applications	0.256	0.373	−0.007	0.088**	−0.340**									
(5) Technological depth per patent applications	0.036	0.076	0.008	0.069**	0.010	−0.021*								
(6) Technological breadth per patent applications	0.990	0.623	−0.024*	−0.060**	−0.100**	0.054**	−0.401**							
(7) Forward citations per patent applications	0.528	2.010	0.005	0.057**	−0.093**	0.041**	0.041**	0.047**						
(8) Hidden champion (dummy)	0.095	0.294	0.001	0.097**	−0.016	−0.007	0.111**	−0.095**	0.025*					
(9) Return to assets	7.234	13.588	0.003	0.052**	0.014	0.013	0.014	0.016	0.023†	0.027**				
(10) Debt-to-equity ratio	139.263	169.050	−0.002	−0.020	0.022†	−0.020	−0.023†	0.005	−0.004	−0.025**	−0.160**			
(11) Blockholder (dummy)	0.830	0.375	0.002	−0.025*	0.004	−0.006	−0.003	0.016	−0.041**	−0.064**	−0.044**	0.020**		
(12) Firm age (log)	3.299	0.977	−0.005	0.068**	0.045**	−0.003	−0.019†	−0.023*	−0.010	0.137**	0.114**	−0.066**	−0.115**	
(13) Firm size (log)	5.060	0.969	−0.019**	0.043**	−0.026*	−0.035**	0.192**	−0.187**	0.016	0.306**	−0.015**	0.022**	−0.002	0.174**

† $p < 0.1$.
* $p < 0.05$. ** $p < 0.01$.

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TABLE 2 Estimation results (H1).

Theoretical construct Hypothesis	Innovation quantity	Innovation efficiency H1
Dependent variable	**Amount of patent applications (log)**	**Patent applications per employee**
Model	**(1)**	**(2)**
Hidden champion	0.291**	0.009
	(0.019)	(0.030)
Return to assets	0.00000	0.00001
	(0.0002)	(0.0002)
Debt-to-equity ratio	−0.0001**	−0.00000
	(0.00002)	(0.00002)
Blockholder (dummy)	−0.047**	0.001
	(0.016)	(0.019)
Firm age (log)	−0.002	−0.0002
	(0.005)	(0.007)
Firm size (log)	0.089**	−0.015†
	(0.005)	(0.008)
Constant	−0.380**	0.097†
	(0.045)	(0.053)
Federal state dummies ($n = 15$)	YES	YES
NACE dummies ($n = 24$)	YES	YES
Year dummies ($n = 9$)	YES	YES
Firm year observations	41,217	41,217
R^2	0.027	0.002
Adjusted R^2	0.026	0.0003
F statistic	1135.540**	65.777†

Note: Random effects panel model. Robust standard errors in parentheses clustered at the organizational level. Two-tailed tests. 4677 different firms, of which 585 are hidden champions, are included in the analysis.
†$p < 0.1$.
*$p < 0.05$.**$p < 0.01$.

noted that the models were run with a declining number of observations as those models focusing on the characteristics of patent activities consequently dismissed observations for which no patent was applied.

Hypothesis 2 proposed that hidden champions have a higher inward orientation regarding sources of technological knowledge than other firms. This was investigated in Model 3 by using *self-citations per patent applications* as the dependent variable. The model showed a significant negative effect ($\beta = 0.188$, $p < 0.01$), supporting H2. Models 4.1 and 4.2 tested Hypotheses H3a and H3b. First, H3a argued that hidden champions have a lower technological novelty. Model 4.1 relied on *backward citations per patent applications* as a novelty measure. The regression coefficient was not significant ($\beta = -0.268$, $p > 0.1$). Hence, we rejected H3a. Model 4.2 tested H3b and used *granted patents per application* as the quality measure. The effect was not significant ($\beta = -0.016$, $p > 0.1$), thus, leading us to no support for H3b. H4 proposed a higher depth and lower breadth of hidden champions' innovations. Model 5.1 tested a higher technological innovation depth of hidden champion innovations (H4a). The effect was found to be positive and significant ($\beta = 0.007$, $p < 0.05$). Thus, H4a was supported. Model 5.2 tested a lower innovation, the effect was marginally significant ($\beta = -0.049$, $p < 0.1$), leading to tentative support for H4b. Model 6 tested H5, a lower technological impact of hidden champions' innovations. The effect was not significant ($\beta = 0.077$, $p > 0.10$), thus leading us to no support for H5.

5.2 | Robustness tests

To investigate the robustness of our results and to address for potential sample selection bias, we applied Heckman's two-step estimation approach. The results are presented in Table 4. This recalculation of our results presented in Table 3, testing H2–H5, confirmed most of our findings. First a probit regression was estimated from which the inverse Mill's Ratio was determined and incorporated, as a predictor, in the second step, that is, an OLS regression testing our hypotheses. This first probit regression (Model 5) focused on a dummy as the dependent variable—named *patent application dummy*—that expressed whether a firm has one or more patent applications in the respective year (coded as 1) or not. To account for a firm's likelihood to apply for a patent application, an additional exclusion variable was introduced in Model 7: *Innovation activity* (*last 3 years*). This variable is a dummy variable expressing 1 if a firm had applied for at least one patent in the previous 3 years. Thus, the innovation activity of a firm, in the previous 3 years of the focal year were taken into consideration. A vital assumption of the Heckman's two-step estimation approach is that the additional variable included in the first-stage probit model does not constitute an independent variable of the second step. Previous innovation activity has a significant positive effect ($\beta = 1.571$, $p < 0.01$) on a firm's likelihood to apply for a patent. This significance as well as the significance of the Mill's ratios in almost all model specifications support the choice of the Heckman selection model.

Model 3 showed that hidden champions are overall more likely ($\beta = 0.291$, $p < 0.01$) to apply for patents

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TABLE 3 Estimation results (H2–H5).

Theoretical construct	Inward orientation of sources of tech. knowledge	Innovation novelty and quality		Innovation depth and breadth		Technological impact
Hypothesis	H2	H3a	H3b	H4a	H4b	H5
Dependent variable	Self-citations per patent applications	Backward citations per patent applications	Granted patents per patent applications	Technological depth per patent applications	Technological breadth per patent applications	Forward citations per patent applications
Model	(3)	(4.1)	(4.2)	(5.1)	(5.2)	(6)
Hidden champion	0.188**	−0.268	−0.016	0.007*	−0.049†	0.077
	(0.050)	(0.219)	(0.015)	(0.003)	(0.026)	(0.066)
Return to assets	−0.002†	−0.002	−0.0001	0.0001	0.001	0.004
	(0.001)	(0.007)	(0.0005)	(0.0001)	(0.001)	(0.003)
Debt-to-equity ratio	0.00004	0.001†	−0.0001†	−0.00001†	0.0001	0.0001
	(0.0001)	(0.001)	(0.00004)	(0.00001)	(0.0001)	(0.0002)
Blockholder (dummy)	−0.015	0.101	0.010	0.002	−0.010	−0.178*
	(0.045)	(0.270)	(0.017)	(0.003)	(0.028)	(0.088)
Firm age (log)	−0.068**	0.008	0.017*	−0.005**	0.026*	−0.034
	(0.018)	(0.102)	(0.007)	(0.001)	(0.012)	(0.032)
Firm size (log)	−0.002	−0.123	−0.009	0.008**	−0.128**	−0.064
	(0.022)	(0.123)	(0.008)	(0.001)	(0.013)	(0.056)
Constant	−0.076	−5.384**	0.208**	−0.038**	1.683**	0.713
	(0.343)	(1.167)	(0.080)	(0.012)	(0.141)	(0.442)
Federal state dummies ($n = 15$)	YES	YES	YES	YES	YES	YES
NACE dummies ($n = 24$)	YES	YES	YES	YES	YES	YES
Year dummies ($n = 9$)	YES	YES	YES	YES	YES	YES
Technology field dummies ($n = 35$)	YES	YES	YES	YES	YES	YES
Firm-year observations	5878	5878	5878	5878	5878	5878
R^2	0.023	0.087	0.071	0.121	0.212	0.030
Adjusted R^2	0.008	0.074	0.057	0.108	0.200	0.016
F Statistic	212.303**	437.160**	384.833**	879.386**	578.421**	188.961**

Note: Random effects panel model. Robust standard errors in parentheses clustered at the organizational level. Two-tailed tests. 1,580 different firms, of which 397 are hidden champions, are included in the analysis.

†$p < 0.1$.

*$p < 0.05$.**$p < 0.01$.

compared to other Mittelstand firms. The results in Table 4 further confirm H2 ($\beta = 0.101$, $p < 0.01$): a higher inward orientation regarding sources of technological knowledge is associated with hidden champions' innovations and a higher technological depth (H4a, $\beta = 0.005$, $p < 0.01$). The weakly supported H4b in Model 5.2 (lower technological breadth) was not supported by our robustness analysis.

As an additional robustness test, we varied our novelty measure, following Jung and Lee (2016). This varied

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TABLE 4 Estimation results of the robustness testing (H2–H4).

Theoretical construct	Auxiliary regression	Innovation orientation	Innovation novelty and quality		Innovation depth and breadth		Technological impact
Hypothesis		H2	H3a	H3b	H4a	H4b	H5
Dependent variable	Patent application dummy	Self-citations per patent applications	Backward citations per patent applications	Granted patents per patent application	Technological depth per patent applications	Technological breadth per patent applications	Forward citations per patent applications
Model	(7)	(8)	(9.1)	(9.2)	(10.1)	(10.2)	(11)
Hidden champion	0.291**	0.101**	−0.240	−0.007	0.005**	0.010	0.081
	(0.025)	(0.035)	(0.157)	(0.011)	(0.002)	(0.018)	(0.063)
Innovation activity (last 3 years)	1.571**						
	(0.020)						
Return to assets	0.001	−0.003**	0.003	−0.0002	0.0001	0.001†	0.004
	(0.001)	(0.001)	(0.006)	(0.0004)	(0.0001)	(0.001)	(0.003)
Debt-to-equity ratio	−0.0002**	0.00000	0.001*	−0.0001*	−0.00001*	0.0001	0.00001
	(0.0001)	(0.0001)	(0.0004)	(0.00003)	(0.00001)	(0.0001)	(0.0002)
Blockholder (dummy)	−0.020	0.001	0.048	0.011	0.003	−0.015	−0.167*
	(0.025)	(0.033)	(0.187)	(0.012)	(0.002)	(0.019)	(0.083)
Firm age (log)	−0.013	−0.077**	−0.038	0.018**	−0.005**	0.019*	−0.029
	(0.011)	(0.015)	(0.079)	(0.005)	(0.001)	(0.009)	(0.028)
Firm size (log)	0.244**	0.074**	−0.092	0.002	0.005**	−0.092**	−0.108*
	(0.012)	(0.018)	(0.104)	(0.006)	(0.001)	(0.011)	(0.050)
Inverse Mill's ratio		0.264**	0.249	0.021†	−0.010**	0.143**	−0.096
		(0.026)	(0.175)	(0.012)	(0.002)	(0.018)	(0.067)
Constant	−3.699**	−0.953**	−6.383**	0.101	−0.003	1.324**	1.124**
	(0.113)	(0.278)	(1.158)	(0.076)	(0.012)	(0.137)	(0.429)
Federal state dummies ($n = 15$)	YES	YES	YES	YES	YES	YES	YES
NACE dummies ($n = 24$)	YES	YES	YES	YES	YES	YES	YES
Year dummies ($n = 9$)	YES	YES	YES	YES	YES	YES	YES

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TABLE 4 (Continued)

Theoretical construct Hypothesis Dependent variable	Auxiliary regression Patent application dummy	Innovation orientation H2 Self-citations per patent applications	Innovation novelty and quality H3a Backward citations per patent applications	Innovation novelty and quality H3b Granted patents per patent application	Innovation depth and breadth H4a Technological depth per patent applications	Innovation depth and breadth H4b Technological breadth per patent applications	Technological impact H5 Forward citations per patent applications
Model	**(7)**	**(8)**	**(9.1)**	**(9.2)**	**(10.1)**	**(10.2)**	**(11)**
Technology field dummies ($n = 35$)	NO	YES	YES	YES	YES	YES	YES
Firm-year observations	41,217	5,878	5,878	5,878	5,878	5,878	5,878
R^2		0.071	0.100	0.072	0.157	0.136	0.035
Adjusted R^2		0.057	0.087	0.058	0.144	0.123	0.020
Residual Std. error		1.057	5.324	0.361	0.070	0.582	2.146
F Statistic		5.028**	7.349**	5.115**	12.211**	10.391**	2.384**

Note: Random effects panel model. Robust standard errors in parentheses clustered at the organizational level. Two-tailed tests.
†$p < 0.1$.
*$p < 0.05$.**$p < 0.01$.

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TABLE 5 Overview of hypotheses, theoretical constructs, measurement, and results.

Hypothesis	Theoretical construct	Measurement	Status	Main analysis	Robustness test
H1	Innovation efficiency	Patent applications per employee	Not supported	0.009	-
H2	Inward orientation regarding sources of technological knowledge	Self-citations per patent applications	Supported	0.188**	0.101**
H3a	Innovation novelty	Backward citations per patent applications	Not supported	−0.268	−0.240
H3b	Innovation quality	Granted patents per patent applications	Not supported	−0.016	0.007
H4a	Innovation depth	Technological depth per patent applications	Supported	0.007*	0.005**
H4b	Innovation breadth	Technological breadth per patent applications	(Weakly) Supported	−0.049†	0.010
H5	Technological impact	Forward citations per patent applications	Not supported	0.077	0.081

†$p < 0.1$.
*$p < 0.05$.**$p < 0.01$.

novelty measure (path-breaking novelty) uses technology classes to build a dummy, indicating the incidence of the first combination of two subclasses. As with the other novelty measure, no significant effects were observed.

Table 5 gives an overview of the results of all analyses.

6 | DISCUSSION AND CONCLUSIONS

6.1 | Main results

The objective of this study was to test several hypotheses about hidden champions' technological innovation outputs derived from a capability perspective. Based on a novel dataset combining firm- and patent-level data, our results show that (as expected) hidden champions have significantly higher innovation outputs. Yet, they are not more efficient regarding innovation compared to other Mittelstand firms from the same industry, size, and age. The sources of technological knowledge of hidden champions seem to be more inward-oriented, as indicated by the higher number of self-citations. The resulting innovations of hidden champions have similar novelty and quality as compared to those of other firms. Moreover, the innovations produced by hidden champions show higher levels of technological depth and indicate lower levels of technological breadth. Finally, we find no difference in the technological impact of innovations by hidden champions and other firms.

6.2 | Contributions to the literature

Our findings make two relevant contributions to the literature. First, we contribute to a better understanding of the particularities of technological innovation outputs by hidden champions. Second, we contribute to the discourse on the effects of capabilities for innovation by highlighting the potential adverse effects of (overly) specified capabilities resulting from the pursuit of niche market strategies.

The results regarding innovation quantity, technological depth (breadth) as well as inward orientation regarding sources of technological knowledge are in line with the qualitative and anecdotal evidence of the characteristics of hidden champions put forth by Simon (1992, 2009, 2022) and taken up by the scholarly community (Audretsch et al., 2021; Benz et al., 2021; Johann et al., 2022; Schenkenhofer, 2022). In this regard, our study increases the understanding and provides robust evidence of what constitutes innovation in successful niche market entrepreneurship—the antithesis of the Silicon Valley entrepreneurship model (Lehmann et al., 2019; Pahnke & Welter, 2019).

In line with the general assumption in prior literature, our results show that hidden champions indeed have a higher innovation quantity as measured by the *absolute* number of patent applications. However, in contrast to arguments raised in prior research (De Massis et al., 2018; Rammer & Spielkamp, 2015), hidden champions were not found to show a higher innovation efficiency as measured by the number of patent applications

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per employee. This is a surprising result, as innovation efficiency resulting from a focused strategy is often cited as one of the main reasons for hidden champion's superior performance. This finding can be explained by the additional resources needed to achieve technological leadership that reduce the productivity advantages of a focused niche market innovation strategy. In contrast to our hypotheses, innovation quality and technological impact were not found to be different for hidden champions. The innovation quality and technological impact was neither higher nor was it lower for hidden champions as compared to other Mittelstand firms of the same size, age, and industry. This finding is not in line with our hypotheses, where we described hidden champions as firms that are somewhat caught in the innovator's dilemma (Christensen, 1997) producing incremental (i.e., innovations with low novelty) innovations of high quality but with low disruptive potential. Yet, it is also not corresponding to the success stories about hidden champions in the public media. It seems that hidden champions are surprisingly unspectacular and "normal" in this regard. They seem neither to build their niche market leadership on high quality but low technological impact innovations nor on low quality but high technological impact innovations. Overall, hidden champions are able to achieve a higher innovation output but do not differ from other firms regarding the nature and characteristics of this output. The differences between hidden champions and other firms exist more in the depth and inward orientation of the technological knowledge leading to these innovation outputs. Although our study does not capture any process measures directly, this observation indicates that the innovation processes of hidden champions may be different from those of other firms. This may constitute an interesting area for future research.

An interesting open point is the direction of the relationship between innovation and hidden champion status. Does hidden champion status influence innovation behavior of does a firm's innovation behavior determine market success and hidden champion status? Based on the capability perspective we assume that hidden champion-specific capabilities imply certain innovation outputs. Yet, the opposite direction may certainly also hold true, particularly when longer time periods are considered. Prior research argues that the relationship between innovation and capabilities is dynamic and reciprocal (e.g., Danneels, 2002), which also applies to hidden champions. Many hidden champions are, in fact, created by inventors with strong innovation skills searching for (or even creating) niche markets with a demand for their innovations. For our dataset, which only spans a few years, we conducted a granger causality test to examine the direction of the relationship. The results showed that the hidden champion status predicts the amount of patent applications ($p < 0.001$) and not vice versa ($p = 0.472$). Yet, more research spanning longer time periods is certainly needed to examine this relationship. This may be a fruitful area for qualitative case study research analyzing in depth the birth and development of selected hidden champions over long time periods.

Going beyond the literature on hidden champions, our study is able to make a contribution to research on capabilities and their impacts on innovation outputs. Based on three distinct capabilities of hidden champions (i.e., niche marketing capability, internationalization capability, and integrative capability), we could provide theoretical arguments on why specific capabilities resulting from a focused niche market strategy influence technological innovation outputs. We thereby also extend the literature from strategic management research on potential disadvantages of niche market strategies (e.g., Teplensky et al., 1993; Toften & Hammervoll, 2009). Reflecting upon the nature of the capabilities of hidden champions, they all incorporate both ordinary and dynamic facets as they are utilized to maintain the status quo and enable the creation of new products. For example, an integrative capability facilitates efficient, high-quality processes and quick alignment of resources to quickly respond to new niche market demands. This is in line with the arguments of Helfat and Winter (2011), who argue that distinguishing the nature of capabilities based on their outputs may not always be possible. In line with their arguments, we see that these partially dynamic capabilities—contrary to common notions (Teece et al., 1997)—do not facilitate radical or disruptive change. Even more, whereas these capabilities are suited to enable continuous innovation in one knowledge domain, they may even hinder more radical changes by limiting the innovation breadth as well as the consideration of external technological solutions. This points to potential adverse effects of dynamic capabilities. If these capabilities are specific to certain strategic orientations (e.g., a focus strategy), they may be effective for the continuous development of new products for specific markets but, at the same time, constitute a potential barrier for more substantial change (e.g., if markets are disrupted or new fundamentally different technologies emerge). For hidden champions, the risk of such path-dependent partially dynamic capabilities (Sydow et al., 2009) or tapping into a competency trap (i.e., firms accumulate and enhance the experience in those domains of activity in which they have the capability and concurrently locking themselves out of other domains) (Danneels, 2007; Levitt & March, 1988) may be exceptionally high. Our initial empirical results and these theoretical

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considerations call for future research that empirically investigates our capability-based framework for hidden champions.

6.3 | Managerial implications

The results of our study have practical implications for owners and managers of innovative hidden champions and Mittelstand firms. It puts the anecdotal evidence about this mystified and sometimes overly celebrated group of Mittelstand firms into perspective. While hidden champions seem to be able to produce a higher quantity of innovation output, they seem unable to do so with fewer resources. Our finding that hidden champions seem to be inward oriented with regard to their sources of technological knowledge compared to other Mittelstand firms of the same size and age and from the same industry can even be interpreted as a weakness of hidden champions. In a world increasingly characterized by rapid technological development and innovations occurring at the intersections of different technological fields, a strong technological inward orientation and skepticism toward innovation collaboration and different forms and modes of (inbound and outbound) open innovation can be dangerous and a severe threat to market leadership. Hidden champions may need to critically reflect on whether their innovation strategy and process may have to be adapted to a world where innovation increasingly happens in (innovation) ecosystems (Granstrand & Holgersson, 2020) and (at least partially) at the boundaries of technological fields (Randle & Pisano, 2021). Pursuing a too much exploitative innovation strategy may limit hidden champions realizing their innovation potential. Some works on hidden champions have already been conducted in this direction. Kirner and Zenker (2011), for example, investigate the role of knowledge angels for the corporate success of hidden champions. Knowledge angels contribute unique expertise to the company and thus combine internal and external knowledge, which is particularly beneficial for the technological advantage of hidden champions. Garaus et al. (2016) analyze ambidextrous Human Resource Management systems using case studies of hidden champions. They find that integrative employment practices support the integration of knowledge within the organization. Following these early works, we need more qualitative and quantitative empirical research how hidden champions can and should adjust their innovation approach to remain competitive in an increasingly dynamic, turbulent and uncertain world of unpredictable technological advancements. Related to this, further research could explore the regional knowledge spillovers between hidden champions and other firms in their home region. Whereas some scholars have argued that the regional embeddedness of hidden champions is one of the core strategic advantages of hidden champions (Benz et al., 2021; Vonnahme & Lang, 2021), others have claimed that due to their rural and peripheral locations, hidden champions are confronted with challenging conditions for successful regional innovation cooperation because of the lack of regionally available knowledge and attractive collaboration partners (Audretsch et al., 2021; Audretsch & Dohse, 2007; Lang et al., 2019). Future research is needed to understand how hidden champions contribute to developing regional ecosystems and clusters of innovation and vice versa.

6.4 | Limitations and avenues for further research

While our study constitutes a thorough and robust effort to analyze hidden champion's innovation activities and characteristics, it certainly has limitations, providing fruitful avenues for further research.

First, the national context of Germany may be special, and not all of our results may be transferable to other countries. Even though Germany is a hotbed of hidden champions and constitutes a fruitful environment for their growth, prior research shows that the hidden champion phenomenon also exists in other countries (Kim & Kim, 2015; Voudouris et al., 2000; Witt, 2015). Future research could build on our study and analyze the innovation characteristics and capabilities of hidden champions in other national contexts.

Another limitation concerns the use of patent applications as an indicator of technological innovation. Hidden champions might not want to patent their innovations for secrecy reasons (Cohen et al., 2000; Lampe & Ihl, 2021). For example, they may decide not to patent their process innovations used in the production or those innovations needed to produce their own machines. While patents are generally considered a good proxy for technological innovation, their use omits "softer," non-technological forms of innovation, such as service or business model innovation (Goetz & Han, 2020). Hence, further research on hidden champion innovation should explore other ways and proxies to measure innovation, such as trademarks (Sandner & Block, 2011), design rights (Granstrand, 2005), or new product introductions (Zahra, 1994). This would allow researchers to gain a broader and more holistic view of hidden champion innovation that focuses not only on patented technological innovation. Previous research has shown that softer forms of innovation, such as business models or service

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innovations, play an increasingly important role in value creation and capture (Chesbrough, 2010; Sjödin et al., 2020; Snihur & Wiklund, 2019).

Third, as noted above, although our study does not capture any process measures directly, our results suggest that the innovation processes of hidden champions may be different from those of other firms. This may constitute an interesting area for future research, where one could take an explicit process perspective on innovation and compare the nature and characteristics of the innovation process of hidden champions and other firms. Methodologically, this would require survey-based, experimental and/or qualitative interview data.

Fourth, a promising avenue of future research could be to investigate the actual content of the patent and the protected inventions. One could use novel methods, such as topic modeling and other machine learning-based approaches (Kaplan & Vakili, 2015), to analyze the particularities of hidden champions' innovation activities further. This type of deeper and more fine-grained research could be accompanied by qualitative case studies on hidden champions and their development over time. Time, and thus the time-invariant nature of our major independent variable is another limitation of this study, forbidding the estimation and testing of fixed effects models. Future research could develop and subsequently use time-variant hidden champion-measures.

Finally, the hidden champion concept and particularly its measurement has clear limitations. In fact, one could argue that the group of hidden champions is heterogeneous and consists of several subgroups of hidden champions. As discussed in the background section on hidden champions above, different types of market leadership exist (e.g., qualitative versus quantitative forms of market leadership). Future conceptual and empirical research is needed to develop more sophisticated hidden champion taxonomies that can distinguish between different types of hidden champions and their relation to innovation. Another related direction would be to develop a continuous definition and measurement of hidden champions. This way, one could run more sophisticated statistical analyses using longitudinal datasets and account for changes in the characteristics of hidden champions over time, which is impossible with the dichotomous definition of hidden champions used in our study.[19]

[19]We used the Hausman test to compare random and fixed effects models. For Model 1, 2, 3, and 5.2, a fixed-effects model was preferred. Yet, due to the time-invariant nature of the hidden champion variable, we still use random effects models. This is certainly a limitation, which we however cannot overcome with our dataset.

Overall, our study contributes to a better understanding of innovation in Mittelstand firms (e.g., Brinkerink, 2018; Decker & Günther, 2017; Werner et al., 2018). Our findings suggest that a deep understanding of technological processes and a somewhat inward orientation regarding knowledge sources together with a deep understanding of technologies and markets are reasons for the historical success of hidden champions from the Mittelstand. In conclusion, we hope that our study will serve as a starting point for analyzing the unique capabilities and related innovation characteristics of hidden champions and the innovative Mittelstand and helps to shed some light on the secrets to their success and the challenges they face in a world of increasing dynamics and uncertainty.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The empirical analysis utilizes data from PATSTAT Global (2022 Autumn Edition) and Orbis, provided by Moody's. Both datasets are available for purchase at https://www.moodys.com/web/en/us/capabilities/company-reference-data/orbis.html, and https://www.epo.org/de/searching-for-patents/business/patstat. The names and locations of the study's hidden champions are openly accessible at https://osf.io/eywk9/.

ETHICS STATEMENT

The authors have read and agreed to the Committee on Publication Ethics (COPE) international standards for authors.

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