On the Waves of Change: The Burden of Knowledge and Strategic Human Capital

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Abstract:

Recent trends indicate reduced entrepreneurship over time and greater challenges in the discovery and exploitation of entrepreneurial opportunities. The concept of the "Burden of Knowledge," or the idea that as the historical body of knowledge grows in a given domain, it becomes harder to innovate due to the cost and effort necessary to master prior knowledge before being able to do so, is gaining popularity as a potential explanation. Work on the Burden of Knowledge has primarily been the domain of economics, and where it has entered the field of strategic management it has focused primarily on firm-level outcomes. In this article, we explore the implications of the Burden of Knowledge for the strategic human capital literature, and build new theory regarding human capital specificity and entrepreneurial human capital in light of a growing Burden of Knowledge. We also introduce a series of contingencies regarding when and how we expect the growing Burden of Knowledge to impact human capital in different circumstances.

Keywords: human capital, Burden of Knowledge, new venture teams, opportunity identification, declining business dynamism.

Introduction

To develop new knowledge and generate innovations, individuals and organizations must often first grasp relevant existing knowledge (Azoulay, Jones, Kim, and Miranda, 2020; Wuchty, Jones, and Uzzi, 2007). In many industries, the development of cutting-edge technology regularly requires an in-depth understanding of past technological paradigms. Similarly, modern scientific advancements are built upon fundamental frameworks, which are necessary starting points for new discoveries. As relevant knowledge within a given domain grows in magnitude, knowledge seekers in the present are burdened with an ever-increasing body of prior knowledge that is necessary to navigate before new knowledge may be generated. While in some domains, new knowledge simply replaces outdated knowledge, in other domains, new knowledge extends old knowledge. New and old knowledge are interdependent, and the mastery of pre-existing knowledge is necessary to acquire knowledge at the frontier. This issue has come to be known as "the Burden of Knowledge" -- the idea that innovations are built on a constantly growing body of past knowledge, which makes future innovation in some domains increasingly taxing to achieve over time (Astebro, Braguinsky, and Ding, 2020; Jones, 2009). The fact that new knowledge tends to complement, rather than replace, old knowledge means that innovators in the present face challenges that their predecessors did not. Empirical demonstration of this phenomenon can be seen in several ways: inventors are older by the time they reach their first invention, innovative teams have consistently grown in size, and knowledge depth has become more useful than knowledge breadth in increasingly specialized inventive spaces (Jones, 2009; Uzzi, Mukherjee, Stringer, and Jones, 2013). Further, studies have started documenting steady increases in knowledge complexity in many technology-based industries (Ding, 2023, Ding, Braguinsky, Choi, Jo, and Kim, 2023), declines in knowledge flows across firms, and declines in mobility and entrepreneurship, while large firms are playing an increasingly important role in innovation relative to startups (Akcigit and Ates, 2019; Bloom et al., 2020).

While the strategic management literature has typically not engaged with the Burden of Knowledge directly, there is a rich research literature recognizing that to innovate, individuals and firms must manage complexity. To manage and operate in the context of complexity, firms deploy various coping mechanisms, such as developing coordinating mechanisms and organizational structures to navigate complex problems (Siggelkow and Rivkin, 2005; Van de Ven, Ganco, and Hinings, 2013), developing simplified representations of complex environments (Csaszar and Ostler, 2020; Gavetti and Levinthal, 2000), and/or designing systems that encapsulate complexity within pre-defined modules (Baldwin and Clark, 2000; Ethiraj and Levinthal, 2004).

While this research literature represents an important complement to the broader discussion of how the Burden of Knowledge impacts firm-level strategy, it has not focused on how changes in the Burden of Knowledge affect human capital. This element is crucial for understanding the firm-level impacts of the Burden of Knowledge, as human capital, as a macro-level asset, is the aggregate of individual knowledge, skills, and abilities (Coff and Kryscynski, 2011; Ployhart and Moliterno, 2011). When faced with an increasing Burden of Knowledge, individuals' innovative efforts are potentially complicated by the various challenges they face in identifying, acquiring, and deploying the knowledge, skills, and abilities necessary for innovation.

We maintain that in industries where the Burden of Knowledge is increasing, human capital will be significantly affected, calling into question several long-held assumptions about when and how firms may create and capture economic value from human capital. Specifically, we expect that the tradeoffs between firm-specific and industry-specific human capital will change as the Burden of Knowledge grows and as more firms innovate at the frontier of knowledge. The ways in which these types of human capital have been theorized to stimulate the creation and capture of economic value between firms and employees will likely undergo changes as the nature of the knowledge that underpins those changes. Further, we expect that the concepts of human capital breadth and depth, long held to be determinants of firms' abilities to innovate as well as to identify and seize entrepreneurial opportunities, will also be subject to change under a growing Burden of Knowledge. Together, these changes may alter assertions in the existing human capital literature about how firms derive superior economic performance from human capital and how innovation, entrepreneurship, and employee mobility occur.

Importantly, the burden of knowledge will also increase the pressure to deploy and utilize coping mechanisms. We expect that, while firms will increasingly use coping mechanisms to mitigate the effects of complexity, these mechanisms will be insufficient to completely reverse or negate the effects of the increasing Burden of Knowledge. Even when firms will successfully navigate increasing complexity, the increasing Burden of Knowledge will still have implications for individuals' human capital resulting in effects on mobility and entrepreneurship choices. This outcome will occur because the Burden of Knowledge affects *what* knowledge individuals acquire, if they want to operate at the knowledge frontier, despite firms deploying coping mechanisms. Complementing other studies that connect decreasing knowledge spillovers and entrepreneurship with increasing Burden of Knowledge (Ding, 2023; Ding et al., 2023), we thus use the human capital lens as an explanation of this relationship.

This article bridges an existing research gap between the nascent discussions of the Burden of Knowledge in the strategic management and economics literatures and long-running discussions of human capital as a strategic asset for the purposes of superior economic performance. We expand upon the current discussions of the Burden of Knowledge in strategy by focusing on human capital. In doing so, we also offer a new perspective to the strategic management literature, which has to date largely held traditional assumptions concerning the cost of gaining and developing knowledge, which, as we explore here, may need to be refined. We provide theoretical richness to discussions on human capital specificity of various types, especially with regards to its impacts on employee mobility. In addition, we re-imagine the role of human capital in entrepreneurial issues such as founding team formation, opportunity recognition, knowledge transfer, and spinouts. Importantly, we develop theory about contingencies that determine when and how predicted impacts of the Burden of Knowledge will be experienced in different settings and circumstances.

Understanding the Burden of Knowledge

The concept of the Burden of Knowledge initially arose in the economics literature as a *post-hoc* explanation of several decades-long trends in the US and other world economies. Jones' (2009) seminal work on the subject observed a number of trends in invention across industries and concluded that innovation had, over time, become harder to achieve. Jones (2009) attributed this increasing difficulty to the fact that each generation of innovators bore the weight of a growing body of prior scientific knowledge and highlighted the core elements of the Burden of Knowledge phenomenon. First, the body of knowledge itself was growing, with old knowledge serving as a necessary building block of the next generation of knowledge. Second, because of cognitive limitations, an individual could not hope to absorb all or most relevant knowledge in a field, making specialization a requirement - Jones' (2009) titular "death of the renaissance man." Greater specialization on an individual level meant that complex, multifaceted innovative projects were significantly more likely to require teams of greater size. Finally, each of these elements altered the underpinning incentives and costs of engaging in innovative or entrepreneurial work, leading to changes in the innovation landscape.

The growth of the body of knowledge, and its challenges, have been observed across multiple settings. Densen (2011) noted the exponential growth of knowledge in the medical field over time, with the rate of doubling the knowledge stock going from 50 years in 1950 to a mere 3.5 years in 2010. Similarly, the number of engineers necessary to achieve a doubling of computer chip density (a common measure of technical advancement) rose by 18 times between 1970 and 2020 (Bloom, Jones, Van Reenen, and Webb, 2020). Accordingly, the time required for an individual to build a knowledge base necessary for new knowledge creation has extended. The length of doctoral programs and the time to first invention for patent holders has grown alongside the growth of the body of knowledge, and the age of successful entrepreneurs has increased as founders must cobble together greater amounts of human capital to successfully innovate (Azoulay et al., 2020; Jones, 2009).[1]

The impacts of these changes have been seen in a number of industry and economy-level trends that have broadly been deemed to lead to a decrease in "dynamism," or a reduction in the "creative destruction" that fuels new firm and new technology generation at the expense of older firms and older technologies and the locus of new knowledge moving from startups to established firms (Akcigit and Ates, 2021; Schumpeter, 1942). A reduction in the flow of workers between and within firms, alongside a reduction in the establishment of new firms associated with a drop in job creation, have been largely attributed to the growing individual- and firm-level costs of the Burden of Knowledge (e.g., Decker, Haltwianger, Jarmin, and Miranda, 2016). Some scholars have proposed that it is the difficulty of transferring knowledge from innovative firms at the frontier of knowledge to laggard firms - due, again, to the complexity and scope of knowledge involved in new innovations - that has led to these macro-level outcomes (Akcigit and Ates, 2021; Ding, 2023). In addition, firms that have historically been at the forefront of innovation, such as smaller high-tech startups, have wilted under the practical and administrative costs of pushing

[1] It is useful to note that the mechanism underpinning the Burden of Knowledge may not be uniform across industries or technologies. For example, the interdependence between old and new knowledge may be less pronounced in software engineering because new tools and programming languages may replace the outdated approaches. The heterogeneity of the Burden of Knowledge and its implications are a subject of ongoing research (Antonelli, Crespi, and Quatraro, 2022; Ding, 2023).

toward the frontier of knowledge, and accordingly have either failed to innovate or have not formed in the first place (Astebro, et al., 2020; Gordon, 2016).

Firms' Strategic Reactions to the Burden of Knowledge

The key mechanism driving the Burden of Knowledge is the interdependence between the cutting-edge knowledge at the frontier and pre-existing knowledge. The notion of interdependence and complexity plays an important role in the strategic management literature.[2] Prior work has examined how interdependencies explain heterogeneity in firm performance (Levinthal, 1997; Rahmandad, 2019; Rivkin, 2000), heterogeneity of performance across industries (Lenox, Rockart, and Lewin, 2006, 2007, 2010), and patterns in modularity (Ethiraj and Levinthal, 2004; Furlan, Cabigiosu, and Camuffo, 2014). Further, extensive literature has focused on the role of interdependence in organizational design while building a theory of optimal organizational choices as contingent on environmental and managerial factors (Rivkin and Siggelkow, 2003; Siggelkow and Rivkin, 2006). For example, research studies develop models to illustrate how environmental turbulence and complexity affect performance for different hierarchies, forms of decision-making structures, or decision authority (Li and Csaszar, 2019; Siggelkow and Rivkin, 2005).

In the extant strategic management literature, interdependence is usually conceptualized as connecting an outcome of a focal decision to another decision. For example, if there is an interdependence between A and B, the outcome of a decision A (called the performance contribution of A) does not only depend on decision A but also on decision B. The literature has frequently described the individual decisions as *knowledge* components or elements (Fleming and Sorenson, 2001; Ganco, 2017) because knowledge about an underpinning mechanism is necessary to make a focal choice. For example, knowledge of thermodynamics and material science may be necessary

[2] Complexity is typically defined as a density of interdependence (i.e., number of interdependencies per decision) (Fleming and Sorenson, 2001; Levinthal, 1997).

to make optimal decisions about the size of the block of a combustion engine. As the technology evolves, the decision about the block size may become interdependent with decisions about the fuel injection system, which in turn depends on knowledge of electronics.

Several streams of research in strategic management address how firms attempt to cope with complexity and interdependence as they arise. A significant challenge when coping with complexity and with specialized knowledge creation and utilization distributed across individuals is that of coordination, which is costly and prone to errors. Strategic management literature has devoted a significant effort to investigate how firms improve their coordination of such knowledge. For example, firms may design organizational structures, hierarchies, incentive schemes and communication channels across individuals and organizational units to enable the exploitation of complex knowledge (Baumann and Siggelkow, 2013; Siggelkow and Levinthal, 2003; Siggelkow and Rivkin, 2006). At the same time, decision-makers and scientists may deploy simplified cognitive representations to make sense of complex problems (Csaszar and Ostler, 2020; Gavetti and Levinthal, 2000).[3] For some type of complex knowledge, it may be possible to compartmentalize complexity into modules and design a modular system (Baldwin and Clark, 2000; Schilling, 2000). Managing modular systems is easier than managing integrated systems because the coordination is mostly contained to within modules while interdependencies across modules are minimized. Strategic management literature has also examined how modularity at the level of knowledge and technology translates into organizational modularity (Furlan et al., 2014; Sanchez

[3] Individuals may also cope by ignoring relevant information and satisficing (March and Simon, 1958; Simon, 1956). However, such behavior may not allow them to reach the knowledge frontier. We take the view of Jones (2009), which maintained that innovation at the knowledge frontier requires specialized knowledge that is combined with interdependent knowledge. We thank an anonymous reviewer for highlighting this nuance.

and Mahoney, 1996).[4] As discussed above, we submit that, while the coping strategies make it easier to cope with complex knowledge, they are unlikely to be sufficient to remove the pressure associated with the Burden of Knowledge if individuals want to operate at the knowledge frontier.

Linking the Burden of Knowledge to Human Capital Economic Value Creation and Capture

It is important then to understand how the Burden of Knowledge manifests in individual- and firm-level human capital. As the body of knowledge individuals and firms must contend with has grown, the primary adaptive response by innovators has been to become specialists. Instead of acquiring knowledge outside of their specialty, individuals have opted to seek out other innovators with complementary knowledge. As the knowledge frontier shifts further out of the reach of individuals' ability, specialization within a field and reliance on other scientists has consistently grown (Agrawal, Goldfarb, and Teodoridis, 2016; Jones, 2009). The ability to generate highly impactful science has increasingly become the domain of research teams rather than individual scientists (Adams, Black, Clemmons, and Stephan, 2005; Uzzi et al., 2013). The usefulness of generated knowledge - both in terms of citation by other innovators and in the generation of real-world applications through patents - has also come to strongly favor teams over individuals (e.g., Wuchty et al., 2007).

This outcome has multiple implications from a human capital perspective, many of which we will explore at greater length throughout this article. Broadly, these changes mean that the ways in which economic value can be created by human capital have changed and will continue to change. Specifically, the ability to innovate using generalists and individuals with broad knowledge bases will decrease in industries where the Burden of Knowledge increases (Melero

[4] Consistent with prior work (Albert and Ganco, 2021; Baldwin and Clark, 2000), we consider modularity to be a design choice while the underpinning complexity is captured by the concept of decomposability (Simon, 1962; 2002). Decomposable or nearly decomposable systems are then easier to modularize. We revisit the concept of decomposability below.

and Palomeras, 2015). The ability to innovate at the frontier of knowledge will rely more on specific types of human capital (which we will discuss in the following section) as well as teams (within and across organizations).

Secondly, the ways in which this economic value is captured will also change. The extant literature on strategic human capital draws a strong link between the specificity of human capital and the ability of a firm or individual to capture the economic value created by it. As the costs and incentives of various specific types and combinations of human capital change, so will the ability of different parties to capture the economic value created by it. In addition, the necessity of collaboration across broader teams and potentially across firm lines will further complicate who captures economic value and when. We discuss these issues below.

Specificity of Human Capital and Potential Changes Under the Burden of Knowledge

One of the main constructs in strategic human capital is the notion of *specificity*, and it is key to the way in which economic value creation may change as a result of the Burden of Knowledge. Specific human capital is specialized and more economically valuable in a certain context whether it is a firm, industry, technology, occupation, or task (Abowd, Kramarz, and Margolis, 1999; Gibbons and Waldman, 2004). In contrast to specific human capital, general human capital is easily transferable and valuable across contexts. However, the more generally usable human capital is, the more mobile it is between firms and contexts, decreasing the ability of a focal firm to extract economic value from it (Becker, 1964; Coff, 1997). The literature has focused on how differences in human capital specificity affect firm performance by investigating the differences in the ability of the firm and employees to both create and appropriate value.

For example, firm-specific human capital has been traditionally thought of as a source of economic value for firms because it loses such value when transferred across firms. Thus, firms have incentives to invest in skills of employees that lead to firm-specific human capital. While theoretically appealing, scholars have recently questioned the practical relevance of firm-specific human capital (Abowd et al., 1999; Campbell, Coff, and Kryscynski, 2012a). At the same time, scholars have argued that human capital that is not specific to a firm (i.e., industry-specific or even general human capital) may be a source of economic value to the firm, if it has complementarities (i.e., interdependence) with other unique resources held by the firm (Campbell et al., 2012a; Morris, Alvarez, Barney, and Molloy, 2017). Importantly, the literature on strategic human capital connects investments in employee skills (whether paid for by an employee in the form of education or by an employer in the form of training) with firm-level performance outcomes. Given that the Burden of Knowledge as a theoretical mechanism connects broader technological trends to potential investments, thinking about the Burden of Knowledge through the lens of strategic human capital may yield novel insights.

Traditionally, firm specific human capital has been considered a more durable source of superior economic performance than general human capital primarily because its reduced applicability outside of the focal firm reduces an individual's economic value on the labor market and accordingly constrains employee mobility (Barney, 1991; Dyer and Hatch, 2004). While the mobility constraints imposed by firm specificity of human capital are complex and conditional on a number of factors (Campbell et al., 2012a; Coff, El-Zayaty, Ganco, and Mawdsley, 2020; Coff and Kryscynski, 2011), overall, the consensus in the literature is that reduced mobility caused by imperfect transferability between firms makes firm-specific human capital a more economically attractive investment for firms and a less economically attractive investment for individuals (Wang and Barney, 2006; Mahoney and Kor, 2015).

Similarly, human capital can be tightly bound to a specific industry or technology setting. In contrast to a firm-specific human capital focus on individual firms' idiosyncrasies, industry-specific human capital is comprised of knowledge that is uniquely tied to a particular industrial setting, including knowledge of specific markets, customers, and technology (Marvel and Lumpkin, 2007; Mayer, Somaya, and Williamson, 2012; Neal, 1995). Importantly, the strategic implications of industry-specific human capital are similar to firm-specific human capital in that both represent labor market frictions that complicate mobility of employees across boundaries - in this case, industry boundaries rather than firm boundaries (Campbell, Kryscynski, and Olson, 2017; Honoré and Ganco, 2023; Pennings, Lee, and Witteloostuijn, 1998).

A less commonly explored conception of human capital specificity is technology-specific human capital. Traditionally, knowledge or skills associated with a specific technology has not received attention in the strategic management literature - this degree of specificity tends to be included under the headline of firm- or industry-specific knowledge. There are, however, some studies that have highlighted the importance of either broad technical knowledge or knowledge of a specific technology as distinct from the other forms of specific human capital (Bapna et al., 2013; Bozeman and Corley, 2004; Chatterjee, 2017). In general, this literature has also tied technically-specific human capital to improved firm performance beyond what is granted by general knowledge. In the context of this study, we use the term industry-specific human capital because it is a more established construct, and we consider it similar to technology-specific human capital. While in some cases technology-specific human capital may be transferable across industries, industry-specific human capital and technology-specific human capital are likely highly correlated.

The traditional human capital literature has focused primarily on the importance of firm-specific human capital over industry-specific human capital (or technology-specific human capital) on the basis that firms are capable of shaping their employees' skill sets via firm routines and incentive systems (Kryscynski, 2021; Wang, He, and Mahoney, 2009). Firms are capable of guiding the development of firm-level human capital by influencing the development of individuals' human capital in a way that maximizes its usefulness for the focal firm and minimizes it for others. In comparison, industry- and technology-specific knowledge are usually shaped by firm decision-makers' choices about technology and it may be more difficult to make such choices solely for the purpose of managing mobility. Implications for mobility are usually indirect and may not affect knowledge transfer between rivals, so industry- and technology-specific knowledge are usually viewed as being somewhat less relevant to management-level decision-making. When the literature has considered cross-industry mobility frictions, it often is in conjunction with firm-specific human capital issues (e.g., Starr, Ganco, and Campbell, 2018).

As the Burden of Knowledge grows, the logic underpinning human capital specificity and its effects possibly changes. First, to reach the knowledge frontier, individuals must hold more specialized knowledge that contains both recent and pre-existing older knowledge. Because achieving such knowledge at the frontier is a cumulative and long-term process (Astebro et al., 2020; Jones, 2009), it is less likely that it will be achieved within the boundaries of a single firm. For example, for R&D workers, complementarities between education including both under-graduate and graduate degree education, postdoctoral training, and applied on-the-job-training in the context of a focal employer may be all highly complementary and interdependent. This interdependence may require that the knowledge acquisition occurring at the focal employer will be less firm specific as it needs to build on a common pre-existing knowledge. For example, R&D employees seeking new drug candidate molecules working at different firms may work on different target applications but may need to use similar tools and methods that were acquired through extensive training prior to joining the current firm. The shift away from limiting knowledge acquisition to firm boundaries thus necessitates and is catalyzed by the development of more standardized tools and methods. While the final pieces of knowledge that allow the focal knowledge worker to achieve knowledge frontier may be firm-specific, they likely represent a smaller portion of the overall knowledge held by the employee.

Another potential issue reinforcing the shift of knowledge acquisition outside of the firm boundaries associated with the Burden of Knowledge may be higher knowledge specialization and thus greater teamwork. Teamwork requires common scientific language, communication, and coordination (Nelson and Winter, 1982; Sommer and Loch, 2004). Narrower specialization in the context of teams requires larger teams and more elements of knowledge that need to be recombined to innovate (Jones, 2009; Uzzi, Wuchty, Spiro, & Jones, 2012). It is less likely that all of the required components will be readily available within the boundaries of the firm. Innovating at the frontier may require finding missing knowledge pieces outside of the boundary of the focal firm either by hiring or by collaborating with outside parties, which in turn, reinforces the standardization of knowledge interactions and lowers the potential for firm specificity. These forces likely lead to the accumulation of human capital that is more industry specific and less firm specific.

The same forces that will push more knowledge acquisition outside of the firm boundaries may also lower the tacitness of the knowledge. Firm-specific human capital is often tacit knowledge that is relevant to specific tasks, routines, and resources within a particular firm, and is thus generally present when one firm can fully encompass the knowledge necessary to carry out a particular task, produce a specific product, or provide a particular service. As the Burden of Knowledge grows, the tasks necessary to generate economic value are more likely to be distributed within the firm (specializations across departments) and across firms (coordination/collaboration between firms), which may require more standardization and codification as tacit knowledge may be more difficult to coordinate (Athanassiou and Nigh, 1999; Kreiner, 2002).

As a whole, these changes brought about by the growing Burden of Knowledge have a few key implications. To innovate at the frontier of knowledge, industry-specific human capital will take primacy, thus increasing historic incentives to invest in industry-specific human capital from the firm and individual side. Economic value creation will be driven more by industry-specific human capital and complementarities between industry-specific human capital and other firm resources (including specific bundles of human capital [Lazear, 2009]) than other types of general or specific HC. In addition, while some of the traditional firm-side benefits of firm-specific human capital will remain in terms of economic value capture, the prevalence of firm-specific human capital in economic value creating/innovative knowledge will likely decrease as the creation and combination of interdependent knowledge components will be more likely to occur outside and across the traditional boundaries of the firm. In this reasoning, we posit that individuals face cognitive limitations (consistent with the central arguments in the Burden of Knowledge) and an increase in one form of human capital usually comes at the expense of other forms of human capital. For example, if the industry requires large investments in industry-specific human capital, it may be difficult for the firm to create high levels of firm-specific human capital at the same time. Further, we note that, in an industry where the Burden of Knowledge is large, the tradeoffs between industry-specific human capital and firm-specific human capital will likely be present despite firms' effort to manage complexity through organizational design choices. This outcome occurs because the Burden of Knowledge will lead to knowledge specialization at the individual level and the mitigating strategies deployed by the firm will only focus on alleviating the negative implications of such specialization, since knowledge specialization is necessary for an individual to reach the knowledge frontier (as argued by Jones [2009]). In line with these observations, we propose the following.[5]

Proposition 1: In industries where the Burden of Knowledge is increasing, the economic value creating potential of industry-specific human capital increases relative to that of firm-specific human capital, thus increasing firms' incentives for employees to invest in industry-specific human capital.

It should also be noted that the firm-specific human capital literature has largely been in agreement on the fact that the greater an individual's endowment of firm-specific human capital the lower their economic value on the labor market and, by extension, the less likely that the focal individual will be mobile across firms (e.g., Campbell et al., 2012a). As a result, the increase in firms' incentives for individuals to invest in industry-specific human capital that we predict will be driven by an increasing Burden of Knowledge might be expected to be accompanied by an increase in mobility for workers, as industry-specific human capital should be more applicable across settings than firm-specific human capital.

We do not expect this to lead to an increase in mobility for workers, however. Even though employees should be increasingly free of the labor market frictions associated with high stocks of firm-specific human capital, their mobility across firms may remain constrained. The growing Burden of Knowledge will not eliminate frictions - in fact, mobility frictions may increase due to increasing specialization in tasks and routines and related increase in interdependence with other knowledge and resources.

First, we note that the role and economic value of general human capital is unlikely to shift due to a growing burden of knowledge. General human capital is represented by standard skills and knowledge that are applicable in all firms and prior literature has measured GHC, for example,

[5] A firm can escape this tension by exiting the focal industry and entering an industry where the Burden of Knowledge is lower. We thank an anonymous reviewer for helping us clarify these tensions.

using number of years of general education (Abraham and Mallatt, 2022; Fraumeni, Reinsdorf, Robinson, and Williams 2009).

Importantly, knowledge that is not general human capital specificity but also is not specific to a firm, such as industry-specific human capital, may become more interdependent with general knowledge. Consider interdependencies in the process by which an individual reaches the knowledge frontier and can begin to innovate effectively. The firm-specific portion of any given knowledge used to innovate is likely to be only a minor final portion that adds to the large body of standardized prior specialized knowledge needed to reach the knowledge frontier. In this example, the "skill weights" conception of human capital, popularized by Lazear (2009), highlights why the generality of the various components of these individuals' human capital endowments will not eliminate labor market frictions for them. The skill weights conception of human capital states that specificity is less an issue of unique individual portions of knowledge, but rather results from a highly idiosyncratic *bundle* of many smaller, more general pieces of knowledge/skill. In just this manner, employees engaging in innovative activities will piece together multiple standardized elements of a human capital portfolio, through their specialized education, work experience, and training, to be combined with the minimized but still relevant firm-specific elements in the focal firm in which they are innovating. This process results in an idiosyncratic bundle of skills which, while broadly cobbled together from standardized "general" sources (including industry-specific human capital and general human capital), is limited in economic value on the labor market due to its unique formulation and interdependencies between skills and complementary assets in the focal organization and other organizations from which elements of the bundle are formed. Accordingly, we note that while firm-specific human capital is likely to be reduced as the Burden of Knowledge grows, the barriers to mobility caused by firm-specific human capital will be emulated by a complex bundle of general and specialized knowledge. Thus, as the technological knowledge becomes narrower and more specialized due to the Burden of Knowledge, the bundles of more general knowledge are likely to become more idiosyncratic and more interdependent with other complementary assets contributing to mobility frictions.

Further, it is useful to note that the benefits in reducing frictions when shifting from firm-specific human capital to industry-specific human capital will decline with the Burden of Knowledge, while the mobility frictions associated with specialization will increase. While industry-specific human capital is more transferable across firms within an industry than firm-specific human capital, the industry-specific human capital is also getting more specialized as a result of Burden of Knowledge, which may lower the number of potential recipient firms that may utilize the human capital leading to fewer employment options. The shift from firm-specific human capital to industry-specific human capital will be increasingly less helpful for mobility as specialization due to Burden of Knowledge increases. Furthermore, the mobility frictions due to interdependencies and idiosyncratic bundles of knowledge likely increase with the Burden of Knowledge. This reasoning leads us to formulate a corollary:

Corollary 1: *Increasing Burden of Knowledge may lead to decreasing mobility despite increasing industry-specific human capital relative to firm-specific human capital, thus increasing the ability of firms to capture economic value created by individuals' human capital despite a lack of firm-specificity.*

Entrepreneurship and Entrepreneurial Human Capital: Configuration, Timing, Economic Value Capture

The impacts of the Burden of Knowledge on human capital value creation and capture will not be limited to incumbent firms. A number of factors may impact the formation of founding teams as the Burden of Knowledge grows. The human capital literature has been home to much research on the nature and characteristics of founding teams, from their size and composition to the circumstances in which they arise. Much like our discussion of the various types of human capital specificity, returning to the underpinning logic of why certain expectations hold for entrepreneurial founding teams' human capital will allow us to highlight the ways in which these expectations will change as the Burden of Knowledge grows.

Knowledge Traits and Knowledge Composition

A key discussion in the entrepreneurial human capital literature is how an entrepreneurial team serves as an aggregator of the necessary human capital to carry out a firm's activities. Founding team human capital is a primary force behind both firms' operational performance and their ability to attract investment (Colombo and Grilli, 2005; Gimmon and Levie, 2010). The human capital literature has highlighted elements such as the distribution of knowledge across team members, the nature of that knowledge, and the degree of heterogeneity in team knowledge composition as relevant aspects of entrepreneurial teams' human capital endowments. Each of these elements is impacted by the growing Burden of Knowledge.

Knowledge depth and knowledge breadth as distributed across a founding team have been linked to the performance of entrepreneurial firms. The breadth of knowledge, as proxied by varieties of work experience, has been proposed as a driver of team innovativeness and performance, while the depth of knowledge, as proxied by founders' shared in-depth experience in an industry prior to founding a firm, has also been shown to be linked to startup performance (Beckman, 2006; Campbell, Ganco, Franco, and Agarwal, 2012; Chatterji, 2009). Recent work has attempted to disentangle the impacts of breadth and depth of human capital on a founding team, proposing that founding teams may achieve the maximum benefit of founding team human capital when combining individual founders having great breadth of knowledge with other founders having great shared depth of knowledge (Honoré, 2022).

The implications of a growing Burden of Knowledge clearly complicate the findings of this research literature. In sectors where Burden of Knowledge grows, and as it becomes increasingly challenging for any individual to reach an effective level of knowledge in more than one field, the archetype of the founder with a great breadth of knowledge will become harder to fill. The time and effort necessary to reach a threshold of acquired knowledge in a domain that is sufficient to be applicable in another firm will serve as a barrier to the creation of "broad knowledge founders." Accordingly, founding teams will be more likely composed of individuals with in-depth complementary knowledge of a single domain. The performance benefits of in-depth industry knowledge may still be possible, but the complementary benefits of combining "breadth founders" with "depth founders" may be harder to achieve (Honoré, 2022).

Proposition 2: In settings where Burden of Knowledge increases, the knowledge endowments of founding teams will more likely be distributed across multiple founding team members rather than within one generalist founder, causing both economic value creation and economic value capture to be spread more broadly across individuals.

Although startups may still be able to achieve breadth of knowledge across (but not within) founding team members, the challenges of innovating at the frontier of knowledge may make this more difficult as well. Entrepreneurial founding team formation is a homophilous process, where individuals who are tightly bound socially connect with one another and form teams based on not only complementary knowledge but also shared backgrounds (Leung, Foo, and Chaturvedi, 2013; Mosey and Wright, 2007; Ruef, Aldrich, and Carter, 2003). However, the situations in which potential future founders might interact are increasingly becoming silos of their own. The likelihood that two individuals with significantly different operational skill sets will work together closely shrinks the more knowledge specialization increases. Thus, the kinds of social connections necessary to connect two individuals with significantly different in-depth knowledge of two separate domains are less likely to form. At the same time, these kinds of connections may become more likely to form between individuals with redundant skill sets borne of in-depth experience in a shared domain. Accordingly, not only will the individual founders with breadth of knowledge become rarer, but also connections between individual founders with depth of knowledge in differing domains may also become rarer. As a result, startups may be drastically less likely to be able to take advantage of the innovative- and performance- benefits of breadth of human capital either within or across founding team members.

The greater homogeneity in skills amongst founding team members that these phenomena will encourage will also have impacts on the way startups function. Teams that lack useful heterogeneity in backgrounds - in terms of both knowledge and prior organizational affiliations - have been illustrated to have difficulty in achieving a number of strategic goals, from attracting new employees with desired skill sets (e.g., Beckman and Burton, 2008), to generating break-through innovations (e.g., Tzabbar and Margolis, 2017), and developing unique HR systems (e.g., Leung et al., 2012). Lack of founding team heterogeneity is not merely an internal issue; external parties, including investors, have been shown to assess firms with a lack of knowledge breadth in their founding team as lower quality and less worthy of investment if the focal firm functions in a high-risk environment (e.g., Manor et al., 2019).

Corollary 2: As the Burden of Knowledge increases, it will become less likely that individuals with in-depth knowledge from different domains will have sufficient contact or shared background to found firms together, reducing the likelihood that startups will benefit from breadth of knowledge across founding team members, making economic value creation from human capital more difficult as a whole.

Homogeneity in human capital backgrounds amongst potential founding team members may not only impact the performance and innovativeness of extant startups, but may reduce the types and number of startups that arise. The types and number of entrepreneurial opportunities identified by prospective entrepreneurs is closely related to the nature of their pre-entry human capital (Canavati et al., 2021; Gruber, MacMillan, and Thompson, 2013). Awareness of opportunities is linked to understanding of the space in which that opportunity exists (Gielnik, Frese, Graf, and Kampschulte, 2012; Shepherd and DeTienne, 2005). The fewer domains represented in the pre-founding experience of a group of individuals who might potentially form a founding team together, the smaller the set of spaces in which they are likely to identify potential opportunities. Accordingly, homogeneity in human capital backgrounds among founders will restrict the potential to found a firm at all, and the degree of novelty of any firm founded.

Importantly, entrepreneurial experience itself as a form of human capital has been identified as a driver of the ability to identify opportunities (Ucbasaran, Westhead, and Wright, 2008, 2009). Given the documented and increasing trend of reduced entrepreneurial dynamism (i.e., fewer entrepreneurs and fewer startups), the number of potential founders is not only lower, but the fact that fewer individuals are likely to have prior founding experience means that the number of opportunities they will identify will also decrease (e.g., Akcigit and Ates, 2021).

Again, this highlights a mechanism by which the Burden of Knowledge limits the ability to create and capture economic value using human capital. Human capital acquisition and development at the individual level trends toward specialization and homogeneity due to the complexity and interdependence of knowledge necessary to innovate at the frontier. Individuals who are more specialized, more homogeneous within teams, and less exposed to broad pre-entry experience are less likely to identify a broad set of entrepreneurial opportunities.

Proposition 3: In settings where Burden of Knowledge increases, the breadth of knowledge that homogenous founding teams (e.g., such as those started by founders who know each other well but have overlapping expertise) hold in aggregate decreases. This, in turn, may decrease the ability of the founders to identify and implement entrepreneurial opportunities, reducing both the ability to create and capture economic value.

Contingencies of the Applicability of the Burden of Knowledge

While the growing Burden of Knowledge will have significant impacts on the nature, value, and uses of human capital at the firm level, there are several potential limiting factors that need to be considered. Not all knowledge will follow the same pattern of additivity up to the frontier of knowledge, leading to some knowledge not being necessary to learn to innovate. Paradigm shifts in different domains may cause some knowledge to be less valuable for future innovators to learn. The way that knowledge is managed within firms may alter the burden of learning on individuals grappling with prior knowledge burdens. Different knowledge domains may have inter-connections that impact the Burden of Knowledge in neighboring domains.

We explore some of these considerations here broadly separated into three categories of contingencies determining the degree to which the growing Burden of Knowledge will be applicable in a particular setting: *rate of change in knowledge in the focal setting, degree to which knowledge in the focal setting is interdependent with knowledge in other domains,* and *degree to which knowledge can be modularized in the focal setting*. While this list is not exhaustive, we consider these three knowledge traits to capture many of the important limitations and exceptions to the propositions set out above. Each contingency is discussed separately below.

Rate of change in knowledge in the focal setting: Knowledge atrophy and paradigm shifts

The first consideration is that knowledge is not uniformly valuable over time. The logic of the Burden of Knowledge phenomenon is that to innovate in domain x at time t, all knowledge generated in domain x prior to time t must be mastered first. This is not necessarily the case; some knowledge remains relevant and necessary for future innovations in a domain while some knowledge "atrophies". An individual "unit" of knowledge in a domain may become less useful over time, as the elements of it that are useful either become unnecessary or are subsumed in other knowledge. For example - while the impact of Gary Becker's seminal 1964 work on human capital is fundamental to the understanding of the strategic human capital literature, a student of the literature today may be less likely to read Becker (1964) than a student in the 1970s might have been. Instead, students may read a plethora of work based on and building upon Becker (1964), perhaps even citing it, while indirectly acquiring the knowledge by works that built upon it. In this manner, the specialized body of knowledge underpinning human capital will consist of some elements that must be learned to reach the frontier, some that may be useful but can potentially be ignored with little consequence, and some that are outright defunct. Accordingly, different domains of knowledge will have differing burdens of knowledge, and the predictions set out above may apply differently as a result. For example, consider two domains in which a large body of prior knowledge exists, where in one all of the knowledge remains integral to new advancement in the field while in the latter there is a high rate of knowledge atrophy. While at first glance innovators in both spaces must grapple with a similar "backlog" of knowledge, those in the latter domain face a significantly easier task in reaching the frontier of their field. Accordingly, they may be afforded opportunities for diversification and broadening of their individual knowledge stock that innovators in the former space will not. These impacts will likely resound through the entire innovation process, driving differential rates of invention, and entrepreneurship.

Additionally, the body of knowledge that is functionally necessary for an innovator to be familiar with to engage in activity at the frontier in their domain will be partially determined by paradigm shifts. As described by Kuhn (1962), the process of the accumulation of knowledge is additive and linear only when primary precepts are shared amongst those within that space. When those primary precepts are changed, a paradigm shift occurs, where the prior knowledge no longer is additive to the new knowledge founded upon new precepts. As an example, physicists innovating at the frontier of their specialization may no longer need to invest time and energy in learning Aristotelian theories of physical matter, which have been superseded by Newtonian physics, while past generations have had to grapple with the cost of acquiring that knowledge before moving on to the work of adding to the body of knowledge. The paradigm shift that came with the acceptance of Newtonian precepts and their replacement of Aristotelian precepts as the foundation of new knowledge had the effect not only of changing the nature of future innovations, but of freeing innovators of the burden of needing in-depth knowledge of the work of those that came before the establishment of the Newtonian paradigm. In a similar manner, individuals or firms that intend to accumulate technical knowledge in the computer processing space currently must build an understanding of the binary bit structure that underpins all current computing; should a future paradigm shift toward quantum computing occur, at least some of this knowledge will no longer be relevant, as the innovations that will come after it will have a new starting point in the quantum era. Accordingly, some of the complications predicted in this essay may have limited implications in domains where such paradigm shifts occur.

Proposition 4: The rate of increasing Burden of Knowledge is not uniform across settings. The effects of Propositions 1-3 and Corollaries 1-2 are contingent on the rate of changes driven by increasing Burden of Knowledge in the focal setting.

Degree to which the knowledge in the focal setting is interdependent with other industries

Moreover, knowledge in one domain may have interdependencies with knowledge in other domains. Accordingly, the Burden of Knowledge in a particular technological space may be impacted by seemingly unrelated advances in other spaces, a sort of external shock for innovation in the focal space. For example, innovation in the pharmaceutical industry depends largely on creating new drugs by assessing the impacts of certain substances, as well as determining the usefulness of extant drugs for new or previously unstudied conditions. During the era of COVID, a great deal of effort has gone into assessing the potential repurposing of extant drugs to address some of the symptoms and impacts of the COVID-19 virus. This effort has been helped along significantly by machine learning algorithms that were not expressly developed for the purpose of drug discovery.[6] In this way, advances in software and machine learning have lessened the Burden of Knowledge in pharmaceuticals, and similar cross-pollination of advances in one domain into another are likely to occur over time, simplifying and advancing the innovation process in one or both of the related domains. Conversely, interdependencies with other domains may increase the Burden of Knowledge in the focal domain. To return to the previous example, if the use of machine learning algorithms becomes a prerequisite for successful research in pharmaceuticals, individuals seeking to innovate in the pharmaceutical domain will be burdened with both the prior knowledge in their focal domain as well as the relevant knowledge in the machine learning space. In such a case, knowledge interdependencies increase the Burden of Knowledge.

Knowledge interdependencies bring discordant knowledge together, leading to innovation potential, but also increasing the overall body of knowledge involved in that innovation (Bartholomew, 1997; Gupta and Maltz, 2015; Miller, Fern, and Cardinal, 2007). In addition, having knowledge distributed across domains often introduces considerable coordination costs between different knowledge domains (Newell et al., 2008; Zhou, 2011). While these coordination costs will continue to exist regardless of the degree of Burden of Knowledge borne by innovators in a space, the potential for knowledge advances from outside of the focal space to affect the Burden of Knowledge faced by an innovator will likely be impacted by the level of coordination costs involved in managing the interdependencies between the relevant disparate knowledge spaces.

[6] Nelson, 2018. Why Big Pharma and Biotech are betting big on AI. NBC news, https://www.nbcnews.com/mach/science/why-big-pharma-betting-big-ai-ncna852246 accessed on July 7, 2022.

Proposition 5: The impacts of the Burden of Knowledge may be either attenuated or amplified by the degree to which knowledge in the focal setting is interdependent with knowledge in other domains. This effect will be impacted by the degree of the coordination costs in managing the disparate bodies of knowledge.

Degree to which knowledge in the setting can be modularized

There are potential tools for the management of knowledge that could make the Burden of Knowledge easier to bear for firms and those innovating within them. Modularity is a design approach that can "package together" discrete elements of knowledge and allow them to be learned more easily or deployed with limited understanding of the architectural knowledge elements. Modularity allows a firm to decompose tightly coupled systems into loosely coupled "modules," thereby decreasing the cost of coordinating and managing knowledge within product development, between units within a firm, and across firms (Baldwin and Clark, 2000; Helfat and Eisenhardt, 2004; Karim, 2006). Modular design can be a strategic response by firms in spaces where the Burden of Knowledge is particularly high, due to interdependence with past knowledge in the same space or across knowledge domains (Baldwin and Clark, 2000; Ethiraj and Levinthal 2004).

The degree to which modular design is possible in a focal setting could have significant impacts on the degree to which the Burden of Knowledge changes innovation outcomes within that setting. Scholars have described systems that can be modularized as decomposable or nearly decomposable (Simon, 1962, 2002). Such systems exhibit a structure of interdependencies with dense and sparse regions allowing for the design of modules. The software industry is a key example of how this contingency may play out. The Burden of Knowledge in the software industry would seem to be quite high - the many generations of coding language and disparate design elements that must be put together to reach the user-friendly software interfaces that both users and developers have come to expect seem daunting. Yet low or no-code software development environments are flourishing, and modern software engineers rarely must concern themselves with the arcane underpinnings of the interfaces they use on a daily basis. The degree of time investment necessary to reach a level of proficiency sufficient to innovate in the software space is shrinking rather than growing, even though objectively the body of knowledge that should comprise the "burden" is growing. This outcome is occurring because a modular approach to this past knowledge eliminates the individual need to learn preliminary and sometimes even intermediate levels of that knowledge; conceptual understanding combined with the knowledge of a specific user interface is sufficient to function and even innovate. Even those with specialized needs have a significant advantage over those that came before them, as they may for example have all basic and intermediate knowledge needs met by using a programming language such as Python, which will meet the basic requirements of individuals in most knowledge settings while allowing modular additions of special use extensions. In a similar way, industries that either fundamentally rely on such modular technology or which embrace inter-firm modularity - with different firms making use of standardized elements from other firms in the same value chain to avoid the knowledge costs associated with those elements - will save individuals significant time and effort investments in developing specialized human capital.

It is important to consider that such a modular design may allow some industries such as software to avoid many of the costly elements of the growing Burden of Knowledge but will also incur costs of its own. Work on industries that have embraced inter-firm modularity has highlighted costs in terms of individual firms' inability to have full ownership of the knowledge involved in their product design and ultimately being unable to make design choices that they otherwise would have with full knowledge control (e.g., Staudenmeyer, Tripsas, and Tucci, 2005). Broadly, a "partitioning of rights" is likely in situations with significant modularity, leading to concerns about issues of intellectual property, financial outcomes, and the design rights (Barzel, 1989; Langlois, 2002). Thus, the idea that modularizing knowledge could or should be undertaken as an explicit bulwark against the costs of the growing burden knowledge should be preceded with the caveat that even in industries that have already begun to modularize to a great degree, such as semiconductors, the costs and potential failures of modularization pose their own challenges (Ernst, 2005; Fang and Kim, 2018).

Proposition 6: The impacts of the Burden of Knowledge may be attenuated by the degree to which knowledge in the focal setting is or can be modularized, but only if the costs of modularization are less than the costs of bearing the Burden of Knowledge.

Discussion and Future Directions

The goal of this article is to outline some of the strategic human capital implications (and human-capital based underpinning mechanisms) associated with the growing Burden of Knowledge. By exploring issues related to the specificity of human capital and its association with entrepreneurial endeavors, we have been able to highlight a number of relevant strategy-oriented considerations for scholars and practitioners exploring issues of human capital and the knowledge frontier. Further, by discovering the ways in which our general expectations are changed or limited by changes in the overall knowledge landscape or how firms deal with knowledge, we are able to enrich our understanding of the boundary conditions and potential moderators of the relationship between human capital and the Burden of Knowledge.

Rather than being in any way exhaustive, this article highlights the broad intellectual spaces in which further scholarly attention is necessary in understanding the *interplay* between strategic human capital and the Burden of Knowledge. In the following section, we emphasize a number of specific topics that we suggest warrant both theoretical and empirical exploration.

Legal Constraints on Human Capital

Considering the potential costs and complications of firm-specific human capital as a deterrent to employee mobility as the Burden of Knowledge grows, it is likely that legal mobility frictions will be an important consideration for future human capital management within firms. Non-compete agreements are one mobility friction employed by firms, which has grown in importance in recent years, providing a legal outlet for firms to explicitly prevent their employees from sharing knowledge or the fruits of their in-firm learning with competing firms (Marx, Singh, and Fleming, 2015; Starr, Prescott, and Bishara, 2021). It seems clear that as the amount of knowledge embodied in employees increases, and as the cost of building and acquiring such knowledge grows ever higher, firms have a greater incentive to make use of legal impediments to the loss of that knowledge. The fact that non-competes have been shown to be more commonly deployed in high knowledge settings and had amplified impacts on highly specialized and high performing innovators seems to corroborate the idea that the underpinning economic value of the knowledge at stake is a driver of non-compete use (Marx, Strumsky, and Fleming, 2009; Starr et al., 2021). The ability of non-compete agreements to prevent both mobility between firms and mobility to startups will become increasingly valuable for firms seeking to prevent their knowledge workers from using their human capital to compete in the same space (Samila and Sorensen, 2011; Starr, Balasubramanian, and Sakakibara, 2018).

However, there are a number of complicating factors that may lead to a different set of outcomes. While the use of non-competes is currently positively associated with the increased economic value of human capital, the multiple impacts of the Burden of Knowledge also changes the baseline mobility of human capital, as broadly explored in this article. As firms and individuals become more specialized and less mobile across settings, the need for non-compete agreements decreases. Two primary opposing changes occur: the economic value of keeping human capital within the firm increases with the greater fit between specialized firms and specialized individuals, increasing the usefulness of non-competes, and the lack of mobility across settings of that specialized knowledge makes it less likely that the non-competes will actually need to be deployed to prevent the loss of knowledge. Accordingly, longitudinal studies of non-compete agreements in settings in which both the economic value and specialization of knowledge are increasing should help to disentangle these effects.

It is worth noting as well that the use of non-compete agreements will be driven more by the broader industry and technology specific human capital held by employees than by firm-specific human capital. While these kinds of agreements currently are at least nominally about keeping firm-specific knowledge from moving directly to a competitor when an employee leaves the focal firm, as set out above the proportion of valuable human capital that is firm-specific is likely to continue to decrease as the Burden of Knowledge grows. Rather than capturing the economic value of firm-specific human capital, non-competes will instead be used to protect the investment made in hiring individuals who have successfully accumulated, over the course of their education and career, the large body of prior knowledge necessary to innovate at the frontier of knowledge. While this does not change the technical legal function of these agreements, it does represent an important shift in their function. Non-compete agreements that are meant to capture firm-specific human capital represent an expectation that the focal individual will gain valuable firm-specific knowledge in their time at the firm, representing an expectation of future economic value. For firms innovating under a growing Burden of Knowledge, non-competes will function more to safeguard the known value of past knowledge rather than the unknown value of future knowledge, which could make non-competes more appealing to firms. These agreements currently represent a transaction cost for firms in terms of drafting, enforcement, and identifying which employees may in the future have sufficient firm-specific human capital to warrant a non-compete. To the extent that non-competes represent a known value (past knowledge) they can be deployed more accurately for employees who already warrant them.

Heterogeneity Between Firms' Approach to Managing Complex Human Capital at the Frontier of Knowledge

It may become increasingly important to explore the ways that different types of firms manage their human capital as the process of building and exploiting it becomes more complex. Many different firm traits that have been used to identify strategic differences in other literatures could be used as a starting point for understanding the heterogeneous impacts of the growing Burden of Knowledge on various types of firms.

We have begun to consider the differences between incumbent firms and startup firms in terms of how their different resource bases impact their relative likelihood to spawn startups when functioning at the frontier of knowledge, and it is likely that there are other significant differences between the two that can be explored in terms of understanding how human capital and the Burden of Knowledge impact one another. For example, incumbents and startups have different networks and different abilities to grow and leverage those networks (Baum, Calabrese, and Silverman, 2000; Kogut, Walker, and Kim, 1995). Incumbents' greater volume and intensity of network connections may allow them to substitute more effectively in-house knowledge resources with external connections to necessary knowledge, giving them further advantages over startups. At the same time, however, startups' ability to gain knowledge quickly from alliances could be a differentiating factor in startups' ability to leverage their greater agility in comparison to established firms.

Considering specific traits of startups will also allow for novel future research. Differences in things like the degree and type of pre-entry experience of founders has been shown to impact performance and the approach of start-ups, and the nature of that pre-entry experience will be subject to the impacts of the growing Burden of Knowledge (Bayus and Agarwal, 2007; Cao and Posen, 2023). Exploring the relationships between different levels and types of pre-entry experience at an incumbent firm and the likelihood of spinouts, as well as how successful those spinouts will be, highlight a future research agenda aimed at understanding the broader impacts of the Burden of Knowledge.

The Role of Artificial Intelligence and Machine Learning

Our above discussion of modularization and other efforts to turn large portions of knowledge into more easily processed discrete "units" leads to considerations of how other major technological advances might impact the nature of learning and the past body of knowledge. Artificial intelligence and machine learning serve as potential substitutes or complements to the arduous manual learning tasks that characterize the Burden of Knowledge. Firms that develop strong capabilities related to the use of artificial intelligence and machine learning may be able to build superior economic performance vis-à-vis firms that are not able to use these technologies (Haenlien and Kaplan, 2019; Jordan and Mitchell, 2015).

At the same time, there may be strategic challenges involved with the overuse of these technologies. Even now, concerns about over-reliance on machine learning outcomes have become an issue of some discussion in medicine and the natural sciences. As machine learning diagnostics begin to outperform medical specialists, reliance on these results may lead to the atrophy of important knowledge at the human practitioner level (Cabitza, Rasoini, and Gensini, 2017; Froomkin, Kerr, and Pineau, 2019). Unlike the "natural" atrophy of less useful knowledge explored in the current article, the atrophy of useful knowledge due to lack of human engagement with problems is poised to be a significant problem for medical practice in the age of machine learning. Similarly, scholars in machine learning itself have begun to sound alarms regarding lay-people relying on the output of algorithms and failing to engage with underpinning problems and their causes (Chiang and Yin, 2022). Understanding the potential negative effects of managers and/or entrepreneurs subjugating their own expertise and decision-making to machine learning algorithms will be an important field of study in coming years.

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