Resource Idling and Capability Erosion

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ABSTRACT

Why would some firms persist with continued operations when facing unfavorable economic conditions? Although prior studies have investigated the roles of uncertainty and sunk costs as sources of inertia, an unacknowledged type of sunk cost associated with temporary suspensions of operations is related to the erosion of existing capabilities. Building on the resource-based view and real options theory, we argue that resource idling contributes to capability erosion and that the anticipated capability loss motivates firms to refrain from idling their resources under demand uncertainty in the first place. The negative effects of uncertainty on resource idling are likely to be particularly strong for firms with superior capabilities and for those having a greater reliance on human capital. Using data on oil-drilling contractors in Texas, the empirical evidence lends support to our theoretical arguments. Our insights suggest that resource idling shapes the development path of capabilities and risks jeopardizing firms' competitive advantages. The seemingly operational decision of temporarily idling resources can therefore be quite strategic for a firm, and hysteresis, or inertia in continuing operations, can preserve firms' capabilities.

Keywords: idling, demand uncertainty, capability erosion, resource-based perspectives, real options theory

The temporary idling of resources is a common way that firms manage resources to address changing market environments (Hutt, 1939; Penrose, 1959). Resource-based perspectives have linked firms' contraction decisions to attempts to alter a firm's resource base in response to economic conditions and have examined their implications for value creation and competitive advantage (e.g., Adner & Helfat, 2003; Karim & Capron, 2016; Sirmon, Hitt, & Ireland, 2007). Similarly, the real options literature provides insights on contraction decisions and the impact on firm value (e.g., Chung, Lee, Beamish, & Isobe, 2010; Damaraju, Barney, & Makhija, 2015; Pindyck, 1988; Trigeorgis, 1996). Though both streams of literature share mutually relevant concerns about reducing the scale of operations, these literatures have developed largely separately from one another. However, it is notable that temporarily interrupting operations can create vulnerabilities in resources and capabilities (Helfat & Peteraf, 2003; Le Breton-Miller & Miller, 2015; Rahmandad & Repenning, 2016), which are needed to take advantage of future growth opportunities (Kulatilaka & Perotti, 1998; Zander & Kogut, 1995). Further understanding these "hidden" costs is important to explain firms' contraction decisions that prior work on retrenchment activities (e.g., divestment, permanent exits, and downsizing) has not captured.

More specifically, existing theory provides limited insights on the linkage between capability erosion dynamics and decisions to temporarily suspend operations under demand uncertainty. The resource-based view emphasizes the importance of resources for superior firm performance (e.g., Peteraf, 1993), so erosion of strategically relevant capabilities is a source of performance heterogeneity (Helfat & Peteraf, 2003; Rahmandad & Repenning, 2016). However, this literature says little about the role of such erosion potential for decisions to respond to external environments (Karadag & Poppo, 2021). Furthermore, as this perspective has largely assumed that excess resources are divested (Sirmon et al., 2007), the decision to temporarily idle unused resources and *reverse* such a decision has been omitted. The real option literature, instead, explicitly focuses on reversibility in those decisions (e.g., Dixit & Pindyck, 2000). However, it has not focused on how capability erosion relates to the value of holding real options. This limitation is of concern for resource idling because the costs to maintain or recover eroded capabilities may impact decisions to defer under uncertainty (Garud, Kumaraswamy, & Nayyar, 1998). The complementarity of the different vantage points of resource-based perspectives and real option theory suggests a theoretical synergy to enrich our understanding of firms' decisions to put resources (e.g., plant, equipment, workers) into the temporary state of "idleness" (Hutt, 1939).

Building on Penrose's (1959) notion that the value of idling resources and reactivating them depends on external inducements and adjustment costs, we join resource-based and real options research by focusing on the role of organizational capabilities in such decisions. More specifically, we develop the argument that capability erosion from temporarily suspending operations is an unacknowledged form of sunk costs. Sunk costs occur when "an expenditure […] cannot be recouped if the action is reversed at a later date" (Dixit, 1992: 108). Traditional economic logic holds they are irrelevant and should be ignored (e.g., Mankiw, 2004; Frank & Bernanke, 2006), and as such the management literature considers any attention to sunk costs as evidence of cognitive bias (e.g., Ross & Staw, 1993; Staw, 1981). However, real options theory suggests in the context of exit decisions (Lieberman, Lee, & Folta, 2017; O'Brien & Folta, 2009) that it is rational to consider them: exit and subsequent re-entry would be costless in the absence of sunk costs; but in the presence of sunk costs, exit and re-entry would entail reincurring those sunk costs. Hence, in the face of uncertainty and the possibility that things might turn around, it is rational to persist for a while when sunk costs are present. Because of capability erosion, we argue, forward-looking considerations of sunk costs in idling are similar to outright exit. In particular, contracting the scale of operations comes with layoffs and turnover (e.g., Argote & Epple, 1990; Benkard, 2000; Brown, Carpenter, & Petersen, 2019), which loom as sources of vulnerability for firms' core capabilities. Firms cannot easily recoup the value of investments in existing capabilities when they temporarily idle, and due to capability erosion, they lose value when they idle resources. So, when restarting operations, firm-specific sources of performance may be eroded.

We empirically test our arguments by using data on oil-gas wells drilled using rigs in Texas over a span of twenty years. We begin by showing that the extent of idling resources indeed has a negative effect on a firm's existing capabilities. We then provide evidence that demand uncertainty negatively impacts the likelihood of idling, and that this effect is strengthened for firms with superior capabilities and a greater reliance on human capital as opposed to automation. We show that the results hold for alternative capability measures and find that our sampled firms with superior capabilities are not recovering faster after temporary suspensions, further suggesting that idling can erode firms' capabilities.

Our paper provides several important contributions to the literature. At a broad level, we integrate real options theory and resource-based perspectives to better understand the antecedents and consequences of resource idling. More specifically, we argue and demonstrate that capability erosion can be regarded as a type of sunk cost that is relevant from a strategic perspective, as it has implications beyond mere capital losses. Our theory and evidence show that these sunk costs matter and that it is economically rational to take sunk costs into consideration regarding idling decisions under uncertainty. By integrating insights from real options theory and the resource-based view to explicate how capability erosion can function as a form of sunk costs, we demonstrate theoretical synergy between these theories. Finally, by shedding light on capability erosion due to temporary contracting of a firm's scale of business, our insights also complement the specific literature on resource reconfiguration, which has studied divestments or permanent exits in response to a crisis (e.g., pandemic outbreaks, political crises, wars) and has focused on capability renewal as an outcome of reconfiguration. Our study provides intriguing insights for management scholars and practitioners: what might seem to be an operational decision to navigate cyclical market environments (i.e., idling resources) can be a decision that is quite strategic for the firm, as it influences the firm's existing capabilities and hence its ability to benefit from future growth opportunities. This suggests that although idling of resources in a downturn for instance may seem attractive based on short-term considerations (i.e., current cash flows), inertia can be rational under demand uncertainty, especially for firms with superior capabilities and greater reliance on human capital in their operations.

THEORY BACKGROUND

Resource-based perspectives on idling decisions

Resource-based perspectives emphasize that managing resources is at least as important as having them (e.g., Penrose, 1959). Resource management through idiosyncratic processes of developing, combining, maintaining, and leveraging resources provides a source of value creation in uncertain environments (Sirmon et al., 2007). By adding, redeploying, recombining, or divesting resources, firms alter their resource base in attempts to expand (i.e., doing more), contract (i.e., doing less), or innovate for strategic renewal (e.g., Karim & Capron, 2016). Such activities can provide value-creating benefits in shifting environments, for instance, by having the option to redeploy resources (Folta, Helfat, & Karim, 2016; Sakhartov & Folta, 2014), by benefiting from inter-temporal economies of scope when partially or completely replacing resources (Helfat & Eisenhardt, 2004), and/or by shedding misaligned and obsolete resources (Anand & Singh, 1997; Kaul, 2012; Moliterno & Wiersema, 2007).

Despite valuable advances from empirical studies on retrenchment, downsizing, and exit decisions (e.g., Adner & Helfat, 2003; Chakrabarti, 2015; Ndofor, Vanevenhofen, & Barker, 2013), far less is known about decisions to idle resources temporarily, which is central to understanding behavior of firms and their scale of operations (Penrose, 1959). Early work in economics has argued in *The Theory of Idle Resources* that "it is better for productive resources to remain idle for a time than to be misused" (Hutt, 1939: xi). Hutt argued that it is not necessarily inefficient to idle resources. Modern resource-based perspectives in strategy do not link to such views, perhaps because of the assumption that idleness should be avoided (Penrose, 1959) and unused or excess resources (if not redeployed) to be divested (Sirmon et al. 2007).

A lack of theorizing about the value of temporary state of idleness in resource-based literature creates at least two important related theoretical issues regarding our research question: First, the literature excludes forward-looking considerations of *reversing* a contraction decision when conditions improve. However, theorizing about reversibility of responses to environmental conditions is important to explain them because the holder of a resource may plan to reverse the idling decision at a later point in time and reactivate the resource (Hutt, 1939). Thus, to avoid myopia in contraction decisions informed by resource-based perspectives, it is important to take organizational dynamics into account that link to the required efforts related to the reversal of the decision. For instance, one executive in our study's industry context recounted: "For me personally, the decision to stack a rig [i.e., resource idling] was hugely impacted by the knowledge of what the reactivation costs would be."

A reversal of the suspension decision (e.g., due improved economic conditions) implies that *existing* capabilities will be needed again after the idling period. However, research on capabilities has predominantly focused on building and developing new capabilities when responding to changing environments (e.g., Teece, Pisano, & Shuen, 1997; Zollo & Winter, 2002). Few research studies in the resource-based view have alerted us to the challenges of an intertemporal knowledge transfer when idling and reactivating technologies (Garud & Nayyar, 1994). Interrupting operations and idling resources could erode existing capabilities, for example due to reduced utilization of a capability (Helfat & Peteraf, 2003), organizational forgetting (Nelson & Winter, 1982), and employee turnover (e.g., Argote & Epple, 1990).[1]

Heterogeneity in performance from capability erosion when interrupting operations and idling resources is firm-specific and linked to the type of resources leveraged. For instance, existing research suggests that the human factor is a central factor in understanding capability erosion. An executive that we interviewed emphasizes this point: “If you end up idling the majority of your fleet, then you run the risk of losing the competence in the organization. If you're a big company, you’re likely to keep enough assets running and people around that you maintain the knowledge somewhere in the company, [but] it’s not necessarily easy to then repopulate that around the organization.” Reducing the human element and replacing it with automation may shape temporal properties of the strategic assets (Rahmandad & Repenning, 2016). A senior project engineer stated: “The software doesn’t forget. […] Automation means that there is some software or equipment which is, as long as it’s maintained, it should just go from sitting idle for six months, a year, two years, and start working again, whereas a person [needs] time that learning curve ramping back up.” Thus, a theory of resource idling needs to take firm characteristics and resource characteristics into consideration.

While scholars have raised the importance of capability erosion for the strategy literature (e.g., Le Breton-Miller & Miller, 2015; Rahmandad & Repening, 2016), less is known about the relationship between such internal erosion and endogenous choices made in the face of exogenous changes and uncertainty (Karadag & Poppo, 2021). When managing resources in uncertain environments, the future potential of resources to create value for the firm is difficult to

[1] Capability erosion is the “systemic loss of effective capabilities already established in an organization” (Rahmandad & Repenning, 2016: 651). Whereas a resource represents an asset or input to production, a capability refers to a firm’s ability to perform a set of tasks in routine activity (Helfat & Peteraf, 2003; Helfat & Winter, 2011).

evaluate (Sirmon et al., 2007). Shedding resources comes with trade-offs – while it may help improve short-term profitability in unfavorable environmental conditions, such action can also have damaging effects on a firm's opportunity to benefit from future upside potential if industry conditions improve. For instance, one executive reflected on the challenge of resource idling in a downturn: "[When deactivating oil drilling rigs], am I losing a crew that I value more than just the short-term dip or is this really a larger downturn? […] What I'd say is, we are pretty hesitant to drop rigs and to deactivate for that reason. We've invested a lot of time and resources and a lot of our intellectual knowledge into getting them [the crew] where we want them to be."

Combining resource-based perspectives with real option theory

To enrich resource-based perspectives in uncertain and changing environments, strategy scholars have pointed to the importance of *real options* in a firm's ability to alter its resource base and reconfigure the firm (Bowman & Singh, 1993: 12; Dai et al., 2017; Feldman & Sakhartov, 2021; Helfat & Eisenhardt, 2004: 1221; Sakhartov & Folta, 2015; Sirmon et al., 2007; Trigeorgis & Reuer, 2017). When facing uncertainty, the flexibility provided by a firm's real options (e.g., to access future opportunities, to withdraw resources partially or completely, or to redeploy resources) represents a potential source of value creation. Seminal works in economics, finance, and operations research have studied idling decisions as flexible capacity choices to temporarily alter the scale of operations (Brennan & Schwartz, 1985; Dixit & Pindyck, 1994, 2000; Kulatilaka, 1988; Majd & Pindyck, 1989; McDonald & Siegel, 1985; Pindyck, 1988; Trigeorgis, 1996). This body of work argues that "operating options" allow firms to increase capacity, reduce output, or shut down operations (e.g., market exit, divestiture, plant closure). Accordingly, firms make decisions about alternative operating modes and *exercise* the option of switching between them (e.g., between remaining active, idling, reactivation) or abandoning as a form of permanent exit (i.e., completely shutting down operations and selling or scrapping resources).

These works assume that idling decisions are (at least partially) reversible and that it is at the firm's discretion to use the inherent flexibility in the decision to exercise the option to idle and restart *without* longer-term organizational consequences.[2] However, the cost of switching when shutting down and restarting operations can influence the likelihood to persist in the current mode (i.e., inertia or "hysteresis") and widen the range of inaction (or the condition of hysteresis) under uncertainty (Kogut & Kulatilaka, 1994, 2001). In other words, while neoclassical, Marshallian economics suggests that firms should suspend production when expected profits from operating are less than zero (Marshall, 1920), real option theory suggests that *ex-ante* expectations about the firms' (sunk) adjustment costs for idling resources and for reactivation could motivate firms to hesitate temporarily contracting the scale of operations (Dixit, 1992). An executive from our context emphasized the assumption of a forward-looking analysis by pointing out: "The decision to [idle] a rig guarantees that if you're ever going to put the rig back to work you are going to take a very significant reactivation cost." This echoes prior work on option values in idling decisions emphasizing that "executives explicitly think about eventual reactivation of [idled drilling] rigs when they make the initial [idling] decision" (Corts, 2008: 281).

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[2] While a large area of research on real options in strategic management has looked at decisions to *create/purchase* options at a premium, such as through minority investments, forming alliances, JVs, R&D investments, licenses (e.g., Trigeorgis & Reuer, 2017), the focus here is on *exercising* operating options and assumes that firms *have* the operational flexibility to temporarily shut down and restart operations. As Trigeorgis (1996: 4; italics emphasized) points out: while many "real options (e.g., to defer, contract, shut down, or abandon a capital investment) *occur naturally*, others may be planned and built in at some extra cost from the outset (e.g., to expand capacity or build growth options, to default when investment is staged sequentially […])." The latter category of real options includes a payment of a premium to purchase the option and have been subject to empirical work in strategy, e.g., on innovative efforts in pharmaceutical industry as initial "bets" on new technologies. Thus, our paper is consistent with the former category of real options.

A limitation in seminal work on real options is that it has largely assumed symmetric costs of switching between operational modes (Dixit, 1992; Kulatilaka, 1988) and often referred to costs of "mothballing" and physical decay (e.g., rusting of machinery) during temporary suspensions (Dixit & Pindyck, 1994). But the costs of temporarily shutting down operations and those from restarting may be asymmetric and qualitatively different (e.g., costs of layoffs versus hiring and training employees when restarting the business during industry recovery). This links to a concern of real option theory that organizational dynamics could influence option values. While traditionally the erosion of option values is linked to competitive preemption or imitation (e.g., Trigeorgis, 1996; McGrath, 1997), idling of technologies can lead to knowledge deterioration that requires additional investments to train employees and refresh organizational routines (Garud & Nayyar, 1994; Miller, 2002) and may influence the value to defer under uncertainty (Garud et al., 1998). These dynamics may be contingent on the types of resources involved. While some studies have shown that firm characteristics determine differences in the reactivation of idled technologies and influence temporary shutdown decisions (Corts, 2008; Moel & Tufano, 2002), some insights suggest that temporary shutdowns can be rare when intangible resources could be damaged (Brown et al., 2019) and firms risk getting locked-out after shutdowns (Ghemawat, 1991). Little is known about the role of capability erosion as a form of "organizational reality" (Trigeorgis & Reuer, 2017) considered in option decisions and the types of resources involved when making idling decisions.

In our theoretical framework, we integrate resource-based perspectives and real option theory by complementing the elements that resource-based perspectives have (i.e., capability erosion; resource characteristics) and do not have (i.e., reversibility in temporary contraction decisions under environmental uncertainty) by elements that real options theory has (i.e., irreversibility/sunk cost considerations under uncertainty; temporary suspension of operations; exogenous uncertainty) and does not have (i.e., internal erosion dynamics; types of idled resources). We begin by developing arguments for the impact of idling resources on capability erosion. With this foundation on the consequences of resource idling, we then build arguments that predict a firm's decisions to idle in the first place. We consider the important role of uncertainty in the decision to *exercise* the option to idle versus to continue operations, and we integrate the role of anticipated strategic losses as such costs related to a firm's capabilities in idling decisions that cannot be recovered when reactivating. Overall, we propose a theory that conceptually integrates capability erosion, demand uncertainty, sunk costs (or irreversibility), and decision interdependence (e.g., current decisions can foreclose the ability to benefit fully from future options) to explain conditions that make decisions to idle resources strategic (Leiblein, Reuer, & Zenger, 2018).

HYPOTHESES DEVELOPMENT

Consequences of Resource Idling for Capability Erosion

Variations in existing capability levels provide an important source of firm heterogeneity (Helfat & Peteraf, 2003). For capabilities to support repeated and reliable performance of an activity at a roughly similar level, they require routines to perform individual tasks and those to coordinate efforts of individuals involved. Over time, capabilities become deeply embedded and tacit in nature, enabling a consistent level of functionality. Since technologies represent repositories of organizational knowledge (Levitt & March, 1988) that make firms resistant to depreciation and productivity decline (Darr, Argote, & Epple, 1995), temporary idling resources may not affect task performance because routines are conserved.

However, a firm's reactions to selection events external to the capability itself may disrupt a capability trajectory (Helfat & Peteraf, 2003). Erosion of the firm's existing capability level can be the consequence of interruption in production and reduced utilization of capabilities due to shifts in the demand environment. More specifically, temporary shutdowns come with reduced operational activities, reallocations, and layoffs (Benkard, 2000; Brown et al., 2019). Physical resources are also linked to employees, skills, and organizational procedures, so idling decisions can have an impact on organizational capabilities. We provide different mechanisms on the relationship between idled physical resources and human resources to develop predictions about the implications of a firm's extent of idling for capability erosion.

One source of capability erosion can be linked to individual and organizational forgetting when temporarily idling resources and deviating from a configuration of interaction patterns, which is induced by turnover, environmental shifts, and inefficient organizational memory (Argote, 2013; Rahmandad, 2012; Rahmandad & Repenning, 2016). In the context of temporary shutdowns, workers whose jobs have been temporarily suspended or reduced (e.g., being furloughed or shifted to part-time work) experience deterioration in their task performance due to losing familiarity with some routines (Mishina, 1999; Zander & Kogut, 1995). Layoffs can also lead to experience loss as firms are often unable to rehire workers (Benkard, 2000; De Holan & Phillips, 2004). At the organizational level, interruptions in production break the continuity and routines of coordinated tasks in the organization with disruptive effects on productivity (Thompson, 2001, 2007), whereas continuous operation facilitates consistent exercising of routines and maintains capability levels (Helfat & Peteraf, 2003; Nelson & Winter, 1982).

Capability erosion has also been linked to vulnerabilities that are rooted in tacitness and complexity (Garud & Nayyar, 1994; Rahmandad & Repenning, 2016). While both tacitness of an intangible resource and complexity in a production system help protect capabilities against imitation, they can also make a capability vulnerable to its weakest link (Le Breton-Miller & Miller, 2015). Core capabilities are often embedded in evolving interdependent routines and processes that are performed by the firm's employees, which allow these resources to work efficiently with other complementary assets in the organization (Helfat & Peteraf, 2003). Contraction decisions based on significant idling of resources are likely to disrupt wide sets of routines and organizational coordination required to maintain underlying capabilities. Thus, temporarily idling resources and deviating from complex configurations of advanced routines and processes makes capabilities fragile, especially when personnel and teams holding tacit knowledge behind these capabilities are laid off.

As workers in declining businesses are often reallocated, temporarily altering the scale of operations can also involve resource reconfigurations of human resources across a firm's remaining productive units. When employees are reassigned elsewhere, they must adapt their skills accordingly. As idling limits available resources, they become devoted to solving new problems, while being diverted away from exercising previous routines and practices underlying the firm's core capabilities (Rahmandad & Repenning, 2016). Such employee reallocations, intertwined with their deviations from once established interaction patterns needed to maintain optimal capability configurations, can exacerbate capability erosion. Taking these mechanisms together, we specify the following hypothesis, which serves as a foundation for our subsequent predictions on the antecedents of resource idling:

Hypothesis 1: The extent of resource idling has a negative effect on a firm's capabilities (i.e., capability erosion).

Antecedents of Resource Idling Decisions

Resource idling in the face of demand uncertainty. The decision to idle resources in a context of unpredictable future demand can be seen as an *investment* decision under uncertainty. Putting a physical resource into a state of temporary suspension requires a cost to idle the resource and then a further cost to reactivate it (Dixit, 1992; Dixit & Pindyck, 1994: 229–244). We argue that capability erosion associated with temporary idling should be considered a sunk cost that bears on these decisions. Though the sunk costs of capabilities have received little attention in strategy and organization literature, they can greatly matter for firms (Helfat & Campo-Rembado, 2016).

We believe that other theoretical perspectives on idling under uncertainty are incomplete. Traditional neoclassical economic theory sees the unrecoverable portion of past investments[3] as "sunk", and it defines such sunk costs as not relevant for today's decisions (e.g., Parayre, 1995). Traditional economics would suggest that firms exit as soon as the net present value (NPV) of continued operations falls below zero. In the case of no sunk costs, this would be the case. In other words, a firm simply "should temporarily stop production when revenues do not cover avoidable cost" (Brown et al., 2019: 772). Following this static view, sunk costs from capability erosion dynamics do not matter for suspension decisions; yet this view does not consider the upside of uncertainty related to a firm's ability to benefit from future demand should conditions turn favorable. Furthermore, the discounted cash flow models from finance focus on the risks of persisting – for instance, uncertainty raises the discount rate, which lowers the present value of maintaining operations and thereby makes suspending or exiting financially optimal (i.e., Brealey, Myers, & Marcus, 2007). There is also a behavioral perspective that considers sunk

[3] For example, if there is a strong market for used capital equipment, firms can resell that equipment upon exiting and recoup much of the prior investments. We thank the anonymous reviewer for this example.

costs, but it relates decisions to remain active under uncertainty to cognitive biases (Staw, 1981; Ross & Staw, 1993). In light of these alternative perspectives, we use a combination of resource-based and real options perspectives to explain why it can be rational to persist for a while when facing uncertainty and see if conditions improve, or what Penrose presciently considered the "avoidance of 'idleness' in resources" (1959: 63).

For real options to be relevant, three conditions have to be met: there is considerable uncertainty; there is the possibility of exercising managerial discretion in the future; and there are significant sunk costs (or irreversibility). While strategy literature has shown that sunk costs and inertia in response to uncertainty explain decisions to divest and exit (e.g., Damaraju et al., 2015; Elfenbein & Knott, 2015; O'Brien & Folta, 2009), temporary suspension decisions are theoretically different because the cost of reactivation needs to be considered when temporarily shutting down.

When exercising the option to temporarily idle and restart, capability erosion comes with layoffs, turnover, loss of experience, and organizational forgetting. If the erosion was fully reversible, then a firm could simply turn on and off their activities, and there would be no inertia under adverse industry demand conditions. However, firms cannot costlessly reverse the idling decision and the erosion of intangible assets when reactivating operations (Brown et al., 2019) – switching back from the idle mode to an active mode is not as easy as common views on operational flexibility suggest (e.g., Kulatilaka, 1988). A firm's turning-off and turning-on paths are distinct and can be costly, as ramping up is not simply ramping down in reverse. For example, operating in uncertain market environments, firms are likely to make errors when shedding resources and making layoff decisions (Sirmon et al., 2007). Given that the locus of the ability to execute activities associated with a capability resides in teams (Stadler et al., 2013;

Winter, 2003), firms often cannot rely on rehiring fired workers, as they face search costs to find new ones and will have to invest in training of new employees (e.g., Dixit, 1989; Benkard, 2000). Recovering from a capability loss can thus be time-consuming and requires efforts to reactivate inventory knowledge and routines to perform individual tasks and coordinate the variety of tasks performed by new workers who lack a prior history in the organization.

As a consequence, the firm can choose to remain active and ride out bad periods despite short-term losses, or what is known as the hysteresis effect (Dixit, 1992). Now consider two possibilities: high versus low uncertainty about how things will evolve in the future. Facing a high demand uncertainty scenario implies that there is a greater chance that market conditions will considerably improve in a few periods and that a firm will later regret idling. In case market conditions get worse, one can use future managerial discretion and idle resources. Firms therefore can wait to see if conditions fail to improve or further deteriorate before idling, and thus truncate the downside outcome of uncertainty. Continuing operations thus avoids the costs of reactivation and enables the firm to maintain access to new growth opportunities tied to market demand without suffering erosion to their capabilities owing to idling. In sum, it is rational to persist for a while in the face of high uncertainty and sunk costs, as long as losses are not too extreme. Based on the assumption that there will be some sunk costs associated with resource idling, demand uncertainty will therefore encourage firms to rationally persist in their operations rather than idle resources. Thus, we posit:

Hypothesis 2: Demand uncertainty has a negative impact on the likelihood of resource idling.

The moderating role of firm capabilities in idling resources under uncertainty. We also expect that the degree to which sunk costs from resource idling exist will vary significantly across firms. Taking a resource-based perspective on idling decisions, one might argue that firms with superior capabilities could quickly ramp down and use their advantage to more effectively ramp up again when conditions improve. So why not just cut the extra cost of active units during unfavorable economic conditions and rely on the firm's superior capabilities when restarting? We will argue that firms with superior capabilities face "strategic sunk costs" (O'Brien & Folta, 2009) when idling resources that create an incentive for decision-makers to remain active and avoid strategic losses associated with idling under demand uncertainty, compared to the case if the firm had not idled.

When a firm competes at higher value of output and/or lower cost, it has an incentive to engage in activities to support and maintain its capabilities (Helfat & Campo-Rembado, 2016; Stadler et al., 2013). Such capability maintenance depends in part on the continuity of personnel, facilities, and equipment involved (Nelson & Winter, 1982; Helfat & Peteraf, 2003; Winter, 2003), as well as on continued investments in capabilities to avoid their erosion (Dierickx & Cool, 1989; Flammer & Ioannou, 2021). Resource idling can be detrimental to a firm's sources of competitive advantage that it has been built over time. Beyond capability erosion, a firm's resource idling can help competitors who may hire the laid-off workers and gain from knowledge spillovers. Losing qualified personnel to competitors may especially benefit those with inferior capabilities to catch up. Such fragility of an advantage in uncertain environments has an asymmetric effect: the advantage is resource-intensive to develop, quick to destroy, and hard to resuscitate (Le Breton-Miller & Miller, 2015). Hence, firms with superior capabilities that idle resources face strategic losses vis-à-vis competitors that remain active, because temporary idling and reactivation erode their relative advantage. By contrast, firms with inferior capabilities may be more willing to idle because the operational cost of remaining active outweighs the benefits of preserving their existing (inferior) capabilities. They may also use a temporary suspension of operations to enhance their capabilities such as via updating routines and technologies, and thus take advantage of an opportunity to catch up. Meanwhile, firms with greater competencies are likely to show more inertia to such upgrades when facing demand uncertainty (Kogut & Kulatilaka, 2001: 754) because the environmental conditions may quickly improve, and it is costly to reverse such decisions.

Therefore, given that there will be cost associated with idling that can be considered a type of sunk cost within the real options framework, it is likely that the higher the sunk costs (i.e., the greater the capabilities that might suffer erosion), the stronger the effect of uncertainty on dissuading idling. A key reason for this effect builds on the notion that firms do not only hold operating options, or the option to scale down and restart, but also growth options for future expansion (Pindyck, 1988). As the cost of switching between different operating modes creates interdependencies between these options, i.e., current and future decisions (Kulatilaka & Trigeorgis, 1994; Trigeorgis, 1996), the decision to idle a resource has strategic implications for the creation of firm value. Having superior capabilities provides preferential access to growth opportunities and captures a share of the industry's upside potential, relative to firms with weaker capabilities (Bowman & Hurry, 1993; Kulatilaka & Perotti, 1998; O'Brien & Folta, 2009). Access to such options to benefit from the upside of uncertainty is an important reason why decision-makers can keep operations alive (Dixit, 1992). However, capability erosion linked to resource idling has a constraining effect on the firm's ability to capitalize on these growth opportunities. As time passes in the idle mode, the chance of getting locked out from access to growth opportunities increases (Ghemawat, 1991). Thus, even if a temporary suspension of operations may seem attractive based on short-term considerations (i.e., current cash flows), firms with superior capabilities are subject to greater inertia and are rationally hesitant to temporarily idle resources under demand uncertainty. We therefore predict:

Hypothesis 3: The negative impact of demand uncertainty on the likelihood of resource idling will be magnified for firms with superior capabilities.

The moderating role of reliance on human capital in idling resources under uncertainty. A key argument in our theory is that the temporary suspension of operations relates to capability erosion due to the linkage of idled resources to employees, skills, and organizational procedures. Processes related to the use of physical resources and human resources in growth and contraction periods are intertwined (Penrose, 1959). As a result, deploying automation in a firm's operations may allow firms to remove "the human element and therefore [yield] a configuration less prone to erosion" (Rahmandad & Repenning, 2016: 667). Automation can be defined as "the use of largely automatic, likely computer-controlled, systems and equipment in manufacturing and production processes that replace some or all of the tasks that previously were done by human labor" (Raj & Seamans, 2019: 3). Empirical studies find support for the labor-replacing effect of automation (e.g., Acemoglu & Restrepo, 2020; Autor & Salomons, 2018). While limited attention in real options theory and the resource-based view has been given to automated technologies as a type of resource, the replacement of human operators with automated resources influences the reversibility of suspending operations and thus offers potential for theorizing about its role for sunk costs when temporarily idling resources.

The enhanced value of operating flexibility to alter the scale of operations from flexible automation allows firms to operate in more volatile part of the market in which assets are cut back first, also because automated technologies are newer, more capable technologies that are expensive to run. As technologies represent repositories of organizational knowledge (Levitt &

March, 1988) that make knowledge more resistant to depreciation compared to knowledge that rests in individual workers (Darr et al., 1995: 1761), automated technologies should help conserve operating routines in an organization and present a lower threat of capability erosion to a firm. Under high uncertainty, automation mitigates the burden of laying off, rehiring, and training workers when temporarily shutting down operations and reactivating. Thus, for firms that rely on automation, the sunk costs of idling and reactivation should be lower compared to firms that rely on human labor to operate their non-automated resources. By contrast, greater reliance on human resources that could be lost during idling exacerbates resource vulnerabilities because of interdependencies between people, skills, and routines that perform individual tasks and coordinate these tasks (Helfat & Peteraf, 2003; Le Breton-Miller & Miller, 2015). In this case, there should be higher sunk costs associated with idling and reactivating resources compared to the sunk costs of firms that rely on automation. Given that uncertainty and sunk costs combine to dissuade idling, capabilities that rely to a greater extent on human capital as opposed to automated technologies might suffer greater erosion, making restarting more costly and, thus, strengthening the effect of uncertainty on the option value of keeping the operation alive. We therefore predict:

Hypothesis 4: The negative impact of demand uncertainty on the likelihood of resource idling will be magnified for resources with greater reliance on human capital (as opposed to automation).

METHODS

Data and Sample

We use data from DrillingInfo, RigData, the Texas Railroad Commission (TRC), and the Energy Information Administration (EIA). The TRC is the state's regulatory commission overseeing all oil and gas drilling in Texas and maintains records of every well drilled in the state. The EIA is the federal agency that maintains macro data on the oil-gas industry. The oil drilling context provides advantages for empirical studies on resources and capabilities (Stadler et al., 2013) and real options (Corts, 2008; Kellogg, 2014; Decaire et al., 2020). As we further explain below, rich data are available on drillers' capabilities that are subject to erosion. The dataset also includes detailed project-level information on firms' decisions to idle rigs. A fleet of rigs represents flexible capacity of an oil driller who can choose to keep a rig active or to idle it in response to market conditions based on oil price developments. Idling decisions in our context are discrete, visible choices of switching operating modes and resource allocation under uncertainty. Data on oil prices developments allow us to capture the construct of exogenous uncertainty in our context, which has been highlighted as a key element when empirically testing real options theory in strategic management (Adner & Levinthal, 2004, Folta, 2005). Our sample covers 102 drillers, 816 rigs, and 39,522 project wells with complete records from 1999 to 2016.

Consequences of Resource Idling: Capability Erosion Analyses

Dependent variable. Our first outcome of interest is the firm's *capabilities* (H1), which we measure for a driller as its intrinsic speed capabilities of drilling oil and gas wells for production. In this industry, a driller's speed of drilling wells reflects the efficiency of its internal routines and processes, technical competency of its engineers, coordination among crew members, and its managerial ability to quickly deploy its people and resources without increasing costs (Boykin, 1999, Kellogg, 2011; Zander & Kogut, 1995). Differences among drillers in their drilling speeds for similar wells are due largely to differences in their underlying capabilities because other capital inputs into the drilling process are unlikely to vary much. Kellogg (2011: 1974) explains how a driller's speed of drilling wells reflects its underlying capabilities: "Given a particular well and rig, there is little scope for substitution between drilling time and labor or capital. Rigs always work 24 hours a day and 7 days a week, and adding crew members cannot increase the rate of penetration. Most capital drilling inputs, such as the casing and tubing that are installed in the well and the equipment on the rig itself, are fixed functions of the well's depth and the particular rig." Thus, a driller's drilling speed reflects its core competency and is the key metric in which they are evaluated by client producers and ultimately shapes their reputation (Boykin, 1999; Kellogg, 2011). If the change in the driller's capabilities in terms of its drilling speed is negative, then we determine that the driller has suffered capability erosion. Our unit of analysis for capability erosion is at the firm-year level.

To estimate firm capabilities in drilling speed, we build on an empirical specification from past research in competitive strategy that estimated firms' intrinsic speed capabilities, capturing the ability to execute projects faster than competitors at the same cost (Hawk et al., 2013; Pacheco-de-Almeida et al., 2015).[4,5] While this specification has investigated firm speed

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[4] Our theoretical framework focuses on the erosion of firm capabilities in general and we would expect that our theorizing can be applied to different types of capabilities. For our empirics and research design, we needed to focus on a set of firm capabilities (among different types of capabilities that can exist) that are particularly relevant in our empirical context. Given the importance of drilling speed for oil and gas drilling firms (e.g., Boykin, 1999) and a well-developed empirical specification to estimate firm capabilities in speed from prior literature, we chose to focus on intrinsic speed capabilities in drilling. We also conducted robustness checks using technological sophistication as an alternative proxy for a firm's capabilities and captured it by the firm's level of technology deployed (see Stadler et al., 2013). We continued to find results supportive of our theory.

[5] Theoretically, the idea of intrinsic speed capabilities relates to how firms differ in their ability to compress time. Investment project development is likely to be subject to time compression diseconomies, the theoretical phenomenon where project costs increase as time is compressed (Dierickx & Cool, 1989). There are several reasons for time compression diseconomies, such as diminishing returns to allocating more resources to a project to go faster, information loss from parallel processing sequential activities to go faster, and the cost premium from pursuing several approaches at the same time to go faster (see Graves, 1989; Hawk & Pacheco-de-Almeida, 2018). Importantly for our study and interest in firm capabilities, firms are likely to differ in their ability to compress time. Some firms may possess a set of managerial capabilities that enable them to deploy people and resources at a faster pace for the same cost, enabling them to compress time at a lower marginal cost than slower competitors. There may be several firm specific characteristics of a firm's operational processes and culture, organizational learning and history, as well as skilled human capital that determine how firms may differ in their capabilities to compress time and execute operations intrinsically faster. For these firms, the theoretical mechanisms underlying time compression diseconomies are less severe, enabling these firms to compress time at a lower marginal cost and achieve operational

capabilities in resource accumulation of large investment projects, we tailor this setup for our estimation approach in our context as follows: In a first-stage regression using drilling projects, we regress the drilling rate of the firm for the project (calculated by taking the total depth of the well and then dividing by the total number of drilling days needed to complete that well) on a set of systematic determinants of the drilling rate. The residual then represents the firm-specific idiosyncratic component of drilling rate that is associated with a firm's capabilities. We then use the residual from the regression to construct a measure of the firm's intrinsic drilling speed.

Specifically, we first run the following OLS model using our drilling speed rate measure at the project well level (indexed for driller i, well w, field f, and year t) regressing a firm's drilling rate for a given well on the factors at the project and field levels:

$$\begin{aligned} DrillingRate_{i,w,f,t} &= \beta_0 + \beta_1\, WellType_{i,w,f,t} + \beta_2\, ProjectSize_{i,w,f,t} + \beta_3\, ContractType_{i,w,f,t} \\ &+ \beta_4\, OilPotential_{f,t} + \beta_5\, OilDemand_{f,t} + \overrightarrow{\beta_6} FIELDDUM + \overrightarrow{\beta_7} YEARDUM \\ &+ \theta_{i,w,f,t} \end{aligned} \quad (1)$$

In this regression, $DrillingRate_{i,w,f,t}$ is the feet per day drilling rate achieved for the given well, $WellType_{i,w,f,t}$ is the type of well (vertical versus directional)[6], $ProjectSize_{i,w,f,t}$ is the total depth of the well, $ContractType_{i,w,f,t}$ is a variable capturing whether the contract is footage, dayrate or turnkey, $OilPotential_{f,t}$ is the expected oil reserves in the current field,

speeds faster at the same cost. This theoretical background then becomes the foundation of how we theoretically think of firm capabilities in drilling speed.

[6] Oil wells vary in their complexity because they involve locating and developing reserves in different types of geologic formations – performing these activities require capabilities, which involve modifying and/or extending a firm's resource base (Helfat et al., 2007). Specifically, the simplest and least technically complex approach is drilling a well "vertically" using a rotary drill technology, which has been around since the early 20th century. Requiring high technical complexity is drilling a well "directionally", which is drilling at different angles through difficult underground rock formations. Being able to perform such complex drilling techniques requires extensive skills and coordination that proxies for underlying capabilities, which need to be factored.

$OilDemand_{f,t}$ captures field demand level in millions of barrels at the time of the drilling, and $FIELDDUM$ and $YEARDUM$ are vectors of dummies capturing fixed effects for field (based on the well's geographic location) and year. The residual $\theta_{i,w,f,t}$ in equation 1 represents firm-specific deviations from the systematic expected drilling rate for a given project. For each focal driller, we estimate this residual value for each of its wells drilled.

Finally, to calculate our dependent variable (*capabilities*), we then take these residuals and standardize them within each field and year subgroup. Next, we average the firm's residuals each year and collapse them to the firm-year level, $\overline{\theta_{i,t}}$, which can be interpreted in the following way: If $\overline{\theta_{i,t}} > 0$, the focal driller was intrinsically 'faster' in drilling than the systematic expected average across projects in a given year; If $\overline{\theta_{i,t}} < 0$, the focal driller was intrinsically 'slower' in drilling than the systematic expected average across projects in a given year. For every driller, this continuous residual-based measure is its intrinsic speed capability in drilling in year *t*, reflecting the idiosyncratic firm capabilities in drilling speed apart from systematic determinants of drilling operations.

Independent variable. To test H1, we use the firm's *extent of idling* as an independent variable, which we capture as the proportion of the focal driller's total number of its rigs that are idled, or "stacked", relative to its total rig fleet in year *t*. Every driller operates a fleet of drilling rigs, each of which is a tall derrick run by a motor that spins a pipe attached to a drill bit to crush through layers of rock sediments to reach pockets of oil and gas reserves deep underground. A driller's rig becomes "stacked" when its drilling operations are suspended or even completely deactivated by disassembling the rig and placing it into storage in the extreme case. To illustrate, for a driller that has a fleet of 10 rigs in operation and 5 rigs are stacked in a given year, the variable *extent of idling* takes the value 0.5.

Control variables. Several factors could influence the relationship between idling and changes in a firm's capabilities. We use theory to develop an extensive set of control variables in our regressions to mitigate estimation bias. We group them at the firm level and environment level. In Table 1, we list the control variables with their definitions and the reason for inclusion to test H1.

Estimation approaches. To test H1, we use several approaches. First, we use fixed-effects regression, or identification by adjustment, to derive a consistent estimate of the impact of the firm's *extent of resource idling* in year *t* on the firm's *capabilities* in *t+1*, while controlling for potential factors that influence the outcome variable. The inclusion of firm-fixed effects accounts for any time-invariant firm characteristics that may affect both a firm's idling and its capabilities. The residual error is clustered by firm to account for unexplained dependencies across time within each firm. Our measurement of resource idling is lagged relative to the subsequent measurement of firm capabilities, and this temporal structure mitigates concerns about reverse causality and/or simultaneity. If the driller's extent of idling is negatively associated with its intrinsic speed of drilling, then we interpret this decline in the driller's capabilities as capability erosion.

A potential concern for our empirics is that a firm's idling decisions are not randomly assigned across firms, creating a challenge for establishing causal inference in the effect of the firm's idling on its capabilities to determine erosion. Therefore, as an additional approach, we employ treatment effect analysis (TEA), or what is known as identification by balancing. Using different TEAs, we attempt to approximate the experimental ideal by creating a treatment group and a control group that are as comparable as possible using matching, or weighting based on a set of covariates but differ only in the treatment. Our matching variables for drillers are size, age, number of clients, resource heterogeneity, technological sophistication, and human capital reliance. Our TEA uses the full sample with drillers that idled some of their rigs as the treatment group and those that did not idle at all as the control group. Here we are only interested in determining generally whether any resource idling at year *t* leads to capability erosion at year *t+1* and *t+2*, compared to firms that did not idle any of their rigs at year *t*.

We use three complementary TEA approaches to yield an estimate of the effect of the firm engaging in some resource idling on its capability erosion: (1) propensity score matching in the first stage selection model and then run a second stage regression using the balanced treatment group and control group, (2) inverse probability weighting in the first stage to then estimate the average treatment effect, and (3) doubly robust estimation, which combines the inverse probability weighting in the first stage with including controls in the second stage regression.[7] These estimation results, if similar to our initial regression results, would provide further reassurance that we are obtaining a consistent estimate of the causal effect of interest, whereby we are adequately accounting for unobserved interdependencies between the firm's idling choice and its capability erosion.

Antecedents of Resource Idling Decisions

In H2-H4, we predict the likelihood of resource idling at the rig level. We focus on idling decisions at the rig, or project, level for several reasons. First, prior empirical work on idling decisions under uncertainty has used the project level as a unit of analysis (Corts, 2008). The

[7] Propensity score matching and inverse probability weighting methods approach balancing differently, where the former balances the treatment group and control group via matching using propensity scores, whereas the latter uses propensity scores to weight different observations in the treatment and control group to achieve balancing. For doubly robust estimation, an attractive feature of this approach is a doubly robust property, where a consistent estimate is achieved if either the selection model or the outcome model is correctly specified (Morgan & Winship, 2014). In other words, if the matching equation is incorrect but the outcome model is correct, or alternatively, if the matching model is correct but the outcome model is incorrect, we still obtain a consistent estimate as long as one of the two equations is correctly specified.

nature of real option constructs and models also suggests a project-level perspective with the potential to link such theory with strategic management theory (Trigeorgis & Reuer, 2017). Since our key argument suggests that strategic considerations can influence temporary suspension of individual operations, analyzing the project level as the unit of analysis with firm-level influences is appropriate (Moel & Tufano, 2002). Second, the use of the project level for analysis also allows us to make use of more granular information in our control structure to capture project-level factors that could influence real option decisions that would otherwise get lost when aggregated at the firm level.

Dependent variable. To test H2-H4, we use resource *idling* as our dependent variable and use a binary indictor that takes the value 1 if the driller "stacks" a given rig in month *t* by suspending its drilling operations and releasing its associated rig crew members, and 0 otherwise.

Independent variables. We measure *demand uncertainty* as the percentage difference of realized demand compared to the predicted level at a given month *t*. It captures the degree to which industry oil demand diverged from the level of demand that would have been predicted based on historical information. The measure is based on estimating the conditional variance on an autoregressive-moving average process of past variance and disturbances, controlling for heteroskedasticity in the time series (Folta & O'Brien, 2003; Oriani & Sobrero, 2008). Specifically, we first obtain monthly measures of US oil demand (millions of bbl). Using monthly oil demand, we run a generalized autoregressive conditional heteroskedasticity (GARCH) model on the time series of demand for the sample period of 1999–2016. This enables us to approximate unique time-varying estimates of demand uncertainty for the industry. Using the GARCH model, we can estimate demand uncertainty as the market forecast error, which is the absolute percentage difference between the value of industry output predicted by the above regression at period t ($\widehat{OilDemand}_t$), and the observed level of demand at t ($OilDemand_t$). For our second independent variable, we use a firm's *capabilities* in a given period, which is based on the driller's intrinsic speed capabilities of drilling wells, as defined above. To capture a firm's *reliance on human capital*, we determine using a dummy whether the focal rig being considered for idling is the traditional type that is fully human-operated, taking the value of 1, as opposed to automated, taking the value of 0.[8]

Control variables. We control for several factors that could impact idling. In addition to similar controls that we also used in the capability erosion analyses, we included additional controls for project-level characteristics and competitive conditions that are specific to the focal rig being potentially idled (H2-H4). In Table 1, we group these factors at the firm level, the environment level, and the project or rig level.

Estimation approach. We use logit estimation to model the firm's idling decisions because our dependent variable is binary. Using this specification allows us to test our predictions on idling choice: whether increasing demand uncertainty lowers the likelihood of the driller idling its rig in *t*; and whether this effect is amplified for a driller having superior capabilities or one relying on human capital to a greater extent. We include firm-fixed effects to account for any time-invariant firm characteristics that may affect our predictors and outcome. We cluster the standard errors by firm. As robustness checks, we also ran multinomial logit and ordered logit models predicting the degree of idling.

[8] A rig that is 'automated' can vary in its degree of automation: A rig can be 'semi-automated' such that many underground drilling activities are automated and requires only a skeletal, or higher degrees of semi-automation can even mechanize many surface tasks like tripping pipe, or it can even be 'fully-automated' and requires no crew members required on the rig. We were not able to observe the different degrees of automation in our data, and thus use a dummy variable.

RESULTS

Tables 2a and 2b show the descriptive statistics and correlations for our variables. Variance inflation factors (VIFs) were significantly below 10, with a min of 1.49 and a max of 3.83, suggesting multicollinearity is not of concern. The correlation matrices in Tables 1a and 1b shows some initial evidence consistent with predictions. For instance, the extent of resource idling is negatively correlated with a firm's capabilities. Also, demand uncertainty is negatively correlated with the firm's idling.

------- Insert Tables 2a and 2b about here -------

Table 3 presents the estimates of the relationship between the extent of resource idling and capability erosion. Model 1 introduces the control variables. Having built relationships with clients in the past, gained field experience and experience from working with complex tasks and sophisticated technologies seem to strengthen a driller's core capabilities. The results also suggest that operating in environments with high munificence facilitates such task performance, perhaps because in such environments critical resources are more likely to be readily available than in environments with low munificence (Sirmon et al., 2007). In Model 2, we test the relationship between the extent of idling and the firm's capabilities. The results show that idling a greater proportion of rigs is associated with a decline in its capabilities ($p = 0.005$). The magnitude of this coefficient suggests that a 10% increase in a driller's proportion of its rigs idled subsequently results in a decline of about 32% in its intrinsic speed capability.

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

We find further support for the first hypothesis from the treatment effects analyses. In Table 4, Model 1 presents the results when using propensity score matching, Model 2 shows the results when using inverse probability weighting, and Model 3 presents the results when using doubly robust estimation. For the table's rows, the top panel compares the capabilities for similar drillers at year *t+1*, where the treatment group consists of those drillers idling some of their rigs at year *t*, and the control group includes those not idling any rigs at year *t*. The three treatment effects models in Table 3 yield a similar pattern showing the effect of resource idling on a firm's capability erosion: the average treatment effect of resource idling at year *t* is associated with decreasing capabilities in the next year *t+1*, compared to the control group of drillers that did not idle. The difference in the average capabilities between the treatment and control groups is significant (all *p*-values across the three matching models are less than 0.02). To further interpret this finding, drillers that idle their rigs on average have capabilities that are inferior to those drillers that did not idle by about 5.49%. These findings are robust when conducting the TEA using the outcome of capabilities at year *t+2*. Overall, we find support for H1.

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

In Table 5, we consider the determinants of a firm's decision to idle at the project, or rig, level. Model 1 comprises the control variables. Consistent with prior work and earlier arguments, larger firms are more likely to idle, yet heterogeneity in the firm's portfolio of rigs reduces the likelihood of idling perhaps because of the increased costs of reallocated workers who need to be trained. Drillers are less likely to idle a rig when they use sophisticated technologies, which provides further support for concerns of capability erosion when using complex and sophisticated technologies (Le Breton-Miller & Miller, 2015). In environments with high munificence, drillers are less likely to exercise the option to idle.

Finding support for H2, Model 2 (Table 5) indicates that demand uncertainty has a significant negative effect on idling ($p = 0.008$). H3 argues that demand uncertainty has a stronger effect on reducing a firm's likelihood of idling for firms with superior capabilities. In support of H3, results in Model 3 show a negative and significant coefficient of the interaction effect between demand uncertainty and firm capabilities ($p = 0.026$). H4 argues that the negative effect of demand uncertainty on a firm's likelihood of idling is stronger when the firm has greater reliance on human capital. As Model 4 shows, a negative and significant coefficient exists for the interaction of demand uncertainty and human capital reliance ($p = 0.039$).

------- Insert Table 5 about here -------

An examination of the marginal effects plots provides further support for predictions in H3 and H4. Specifically, for H3, we examine the probabilities of idling under different levels of uncertainty for firms having high capabilities (1 S.D. above the mean) and those having low capabilities (1 S.D. below the mean). While firms having high or low levels of capabilities are less likely to engage in idling as demand uncertainty increases, the negative effect of uncertainty on idling is more pronounced for firms with superior capabilities (see Figure 1). For H4, it is evident that the negative effect of uncertainty on idling is more pronounced for firms having reliance on human capital, as compared to firms having reliance on automation (see Figure 2).

------- Insert Figures 1 and 2 about here -------

Supplemental Analyses

Choosing different modes of idling. Whereas our main analysis investigates idling as a general phenomenon, our context allows us to examine different modes of idling, which are "partial idling" and "complete idling". The former idling mode represents a more flexible temporary suspension by laying off only some crew members, while keeping others on standby and the physical rig structure intact, which is also called "warm stacking". The latter idling mode is a less reversible decision because the entire crew is laid off, the rig is deactivated, disassembled, and transported into storage, which is also called "cold stacking" (Corts, 2008:

278–279). For our theorizing to hold, our predicted effects should be stronger for complete idling as it is more costly to reverse. Furthermore, “partial idling” provides an interesting strategic compromise between persisting (staying active) and shutting down: on the one hand, the firm can minimize its capability erosion to better maintain the firm’s competitive positioning to capture future growth options (by being active partially), while on the other hand, it can reduce its operational costs (by being inactive partially).

Thus, we test whether firms engaging in “complete” idling suffer greater capability erosion compared to those engaging in “partial” idling. We find that both coefficients for these different idling modes are negative and significant, but that the coefficient and corresponding economic magnitude for complete idling is greater compared to those on partial idling. These findings (see Table A1 in online appendix for details) suggests that “partial idling”, while possibly more strategically appealing in responding to uncertainty than “complete idling”, is not costless in regard to capability erosion. Then, we test whether firms under demand uncertainty are less likely to engage in higher degrees of idling, and whether this effect is stronger for those firms having superior capabilities. For this outcome, we measure the degree of idling for a given rig in increasing order: if a driller’s rig is kept active and thus “non-idled” (= 0); if a rig is “partially idled” or so-called “warm stacked” (= 1); or if a rig is “completely idled” or so-called “cold stacked” (= 2). Using ordinal logit (see Table A2 in the online appendix), we find that uncertainty has a negative effect on the degree of idling ($p = 0.012$), and that having superior capabilities strengthens this negative effect ($p = 0.029$).

Additional robustness checks. We carried out additional tests to ensure the robustness of our findings. First, in further testing H1, we constructed a measure of capability degradation as the difference in the firm’s capability level from t to $t+2$, and we found results similar to our main prediction that a firm's extent of idling is positively associated with greater capability erosion. Second, in further testing H2, H3 and H4, we examined whether our predictions hold for idling at the firm level by changing our outcome to the driller's extent of idling, which we measure as the proportion of the driller's rigs that are idled among its fleet. We find that our predictions remain robust. Third, we tried several alternative constructions of our predictors. For instance, we used alternative measures of firm capabilities such as its technological sophistication (see also footnote 1), and we continue to find support for our theoretical expectations. Finally, we identified influential outliers using regression diagnostics, and our results remain robust when omitting these observations.

DISCUSSION

Theoretical Contributions

Our insights advance the resource-based view by shedding light on the role of sunk costs when managing resources under uncertainty. Helfat and Campo-Rembado (2016: 261) observe that sunk costs of capabilities have received little attention from strategy and organization scholars and emphasize that these "sunk costs can matter a great deal." We build upon and extend this literature by introducing capability erosion as a form of sunk cost that is relevant for firms' investment decisions under uncertainty. While prior work has provided initial theoretical arguments for the potential vulnerabilities of resources and capabilities (e.g., Garud & Nayyar, 1994; Le Breton-Miller & Miller, 2015; Rahmandad & Repenning, 2016), we integrate resource idling into such considerations and provide empirical evidence on how resource idling contributes to anticipated capability erosion and thus firms' decisions to idle versus persist in the first place. By devoting attention to capability trajectories at the maturity stage of the capability lifecycle, which traditionally has received much less attention relative to building and developing new capabilities to adapt to changing environments (e.g., Teece, Pisano, & Shuen, 1997; Zollo & Winter, 2002), we enhance our understanding of how firms make investment decisions and how these decisions bear upon their *existing* capabilities over time.

Our study also contributes to the emerging literature on resource reconfiguration, which involves processes such as contraction (i.e., doing less) and expansion (i.e., doing more) to create value and secure competitive advantage (e.g., Karim & Capron, 2016; Karim & Kaul, 2015; Vidal & Mitchell, 2015). Our insights contribute in at least two ways: First, we introduce the notion of *temporary* contraction as a temporary deviation from a current configuration. While the reconfiguration literature has largely looked at various reconfigurations for growth, retrenchment, etc. (e.g., Chakrabarti, 2015; Karim & Capron, 2016; Ndofor et al., 2013), temporary reconfigurations imply switching back to prior configurations. Such reversal makes capability erosion relevant for the reconfiguration literature, which has predominantly looked at capability renewal as an outcome of capability trajectories (for a review see Karim & Capron, 2016). Second, by introducing strategic sunk costs into forward-looking considerations in temporary reconfiguration decisions under uncertainty, we shed light on an unexamined linkage between contraction and expansion in the reconfiguration literature. Specifically, we suggest that capability erosion can create interdependencies between current contraction decisions and the ability to benefit from future growth opportunities. Because the effect of resource idling cannot simply be reversed, especially for firms with superior capabilities, our insights suggest that expected capability erosion can explain a firm's choice to persevere rather than reconfigure in response to environmental shifts (Chakrabarti, 2015; Li & Tallman, 2011).

By providing a new theoretical synergy between the resource-based view and real options theory, we advance our understanding of why a seemingly irrational action for firms – to persist despite unfavorable conditions – can be rational. We argue that theoretical arguments from neoclassical economics, finance, and behavioral perspectives are incomplete in explaining firms idling decisions under demand uncertainty because they either ignore the role of sunk costs associated with resource idling and reactivation or they associate such decisions with cognitive biases. We provide empirical support for the debate that option values provide a possible reason why firms appropriately incorporate sunk costs into such decisions (Friedman et al., 2007; O'Brien & Folta, 2009; McAfee, Mialon, & Mialon, 2010). Our interviews with executives and prior statements on real option considerations by executives proxied through reactivation cost (Corts, 2008) strengthen our interpretations of the empirical findings. Though the real options literature has theoretically and empirically studied sources of inertia (or hysteresis due to sunk costs) in response to uncertainty (Baldwin, 1989; Belderbos & Zhou, 2009; Damaraju et al., 2015; Dixit, 1989, 1992; Kulatilaka & Trigeorgis, 1993; Kogut & Kulatilaka, 1994; O'Brien & Folta, 2009), we use a resource-based perspective to identify a particular source of sunk costs that has been unexamined in existing applications of real options theory. Future research using the real options lens might incorporate the role of capabilities in firms' investment decisions and the specific role played by capability erosion as a source of hysteresis in different contexts.

In light of prior debates on what makes a real option effect vis-à-vis other theoretical explanations for resource allocation (Adner & Levinthal, 2004; Cuypers & Martin, 2007, 2010; Folta, 2005; McGrath, Ferrier, & Mendelow, 2004), our research design enables us to examine a real option effect in temporary suspension decisions that real options theory and the resource-based perspective alone do not address. While prior empirical work has shown that both organizational capabilities (e.g., Stadler et al., 2013) and demand uncertainty directly affect resource allocation decisions (e.g., Brennan & Schwartz, 1985), a real option effect tied to the resource-based arguments would suggest that firms are differentially subjected to uncertain environments because of differences in firm capabilities. Our insights provide support for such an interaction effect and help answer important questions in strategy, such as why firms behave differently under uncertainty (Rumelt, Schendel, & Teece, 1994) and how firms facing the same options can achieve different performance outcomes in cyclical industries (Trigeorgis & Reuer, 2017). Our study therefore addresses previous critiques that real option research ought to include erosion dynamics to better address organizational realities (Garud, Kumaraswamy, & Nayyar, 1998). By deploying the resource-based perspective to explicate capability erosion as a form of sunk cost within a real options framework that models idling decisions under uncertainty, our insights thus address the foundations of strategy and call for future research that links real options theory to strategy to better explain heterogeneity in firm behavior under uncertainty and changes in competitive advantage (Leiblein, 2011; Trigeorgis & Reuer, 2017).

Limitations and Future Research Directions

Our study has several limitations that future research might address. First, our study is limited to one industry with usage-specific resources and firms exposed to the same environmental shocks (i.e., oil price movements). Our dataset is unique in capturing the best proxies we can for research on our topic, yet the data do have limitations, such as not being able to directly observe the buildup of capabilities in other value-chain activities (e.g., R&D) and other potential factors affecting idling such as union contracts and other labor relations dynamics. Nevertheless, we believe our context may be a conservative one to test our theory, as our predictions may even be stronger in more knowledge-intensive industries (Garud & Nayyar, 1994; Miller, 2002).

Future research could explore antecedents and consequences of resource idling in other cyclical industries (e.g., mining, aircraft, shipping), examine idleness of different forms (see Hutt, 1939), extend our insights to capability erosion dynamics related to new capabilities rather than established capabilities (e.g., Helfat & Peteraf, 2003), and explore other exogenous events for which companies have different degrees of discretion to idle resources (e.g., pandemic outbreaks, natural disasters, political crises, war). For instance, in Spring 2020, some executives raised concerns about capability losses in the near future due to projects that would be stopped or delayed during the Covid-19 crisis (Watkins & Yaziji, 2020). Though firms faced the same crisis, they responded in various ways. For instance, the media reported that some U.S. drillers had shut off their wells more quickly than anticipated, while others either did not cut drilling-related spending as heavily or even continued their operations at pre-crisis levels (*WSJ*, 2020). While our research helps shed light on those decisions, future work can explore firm-specific expectations of environmental change, and research on strategic responses to crisis provides an opportunity to explore trade-offs in such decisions and alternative responses (Wenzel et al., 2020). While demand in our context is largely influenced by oil price developments and environmental shifts often assumed to be exogenous, future research could extend our arguments to contexts in which environments are more malleable (Reeves, Love, & Tillmanns, 2012) and shifting demand conditions subject to endogenous actions and interactions of competing and/or collaborating firms.

The accelerated shift into automation during the Covid-19 pandemic (e.g., Beane & Brynjolfsson, 2020; Horn & Jackson, 2021) provides another promising avenue to develop our theory in the face of enhanced digital transformation and related upskilling efforts. While we consider automated resources that primarily substitute for human capital, there can be some subcomponents of automated technologies that can complement human capital, e.g., experts that manage and maintain them. Future research can examine more refined measures of automation and other complementary resources and knowledge assets that are non-rivalrous in use.

Future research could also build upon and extend our theory to other strategic responses to external shocks, such as redeployment, innovation, divestment, and market exit. Resource-based perspectives have emphasized different possible branching of capability transformation after external shocks, such as renewal, recombination, replication, and retirement (Helfat & Peteraf, 2003). Corporate strategy research could extend our framework to the concept of switching options and enhance our understanding of organizational inertia and hysteresis in resource (re)allocation when facing technological shifts, shifts in global market preferences, and changing international production conditions for MNCs (Belderbos & Zou, 2009; Dai et al., 2017; Feldman & Sakhartov, 2021; Kogut & Kulatilaka, 1994, 2001; Lee & Song, 2012; Magliolo, Madson, & Walker, 2020; Sakhartov & Folta, 2014). Researchers could also explore initiatives to curate resources and enhance recovery from erosion (Garud & Nayyar, 1994; Le Breton-Miller & Miller, 2015). For instance, with the restart of economic activity during the Covid-19 crisis, in an attempt to ramp up services, airlines needed to retrain furloughed or laid-off pilots due to a lack of practice and forgetting (*NYT*, 2021). Research in these directions could advance our understanding about how firms respond to changing environments and, in so doing, shape their capability trajectories and competitive advantages over time.

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Table 1: Control variables

Variable	Description	H1 tests	H2-4 tests	Rationale for inclusion
Firm				
Firm age	# of years in oil drilling industry	x	x	Proxies the maturity in capacity to manage drilling projects (Boykin, 1999).
Firm size	# of rigs in a driller's fleet	x	x	Firm size can affect idling incentives (Corts, 2008) and ability to transfer employees across locations (Moel & Tufano, 2002).
Number of clients	# of a driller's clients prior to the focal year (t)	x	x	Interrupting operations can fracture relationships with key stakeholders and reduce drilling performance (Kellogg, 2011).
Abandoned rigs	% of rigs sold from the fleet in t	x		Abandonment as proxy for resource reallocation (Klingebiel & Adner, 2015). Divesting as process of shedding resources (Sirmon et al., 2007)
Field experience	# of distinct oil fields drilled prior to t	x		Drilling in different fields can develop competencies due to significant geological variations across fields (Kellogg, 2011)
Prior task complexity	% of 'directional' wells (i.e., most complex type of wells) drilled among previously completed wells	x		Engaging with complex tasks can help discover subtle interdependencies in capabilities and build robustness (Le Breton Miller & Miller, 2016).
Resource heterogeneity	# of distinct rig models in a driller's rig fleet in t	x	x	Heterogeneity can limit resource fungibility (Anand & Singh, 1997) and influence capability erosion (Rahmandad & Repenning, 2016).
Technological sophistication	% of technologically advanced rigs in the fleet (i.e., directional drilling and use of hydraulic legs)	x	x	Complex routines of sophisticated technologies (Stadler et al., 2013) can be vulnerable to erosion (Le Breton-Miller & Miller, 2015).
Human capital reliance	% of rigs in the fleet that are fully human-operated	x		Automation may reduce capability erosion (Rahmandad & Repenning, 2016).
Other rigs revenue	Average revenue of a driller's other rigs (excl. focal rig) in t		x	Value of other firm assets can influence idling (Moel & Tufano, 2002).
Other rigs already idled	% of the focal driller's other rigs already idled in t		x	Idling additional rig can depend on other unutilized rigs (Pindyck, 1988).
Environment				
Environmental munificence	Using 5-year windows, we regressed industry sales on a year-counter variable. The degree of growth or decline is the estimated regression coefficient divided by the mean value of industry sales over the measured period (see McNamara, Haleblian, & Dykes, 2008)	x	x	Environments of low munificence can increase difficulty of shedding resources (Sirmon et al., 2007). Growth/decline phases influence option to contract in cyclical industries (Bollen, 1999; Majd & Pindyck, 1989).
Competitive density	# of incumbent rival drillers active in the same oil field as the focal rig		x	Proximity to competitors offers alternative employment for workers (O'Brien, Folta, & Johnson, 2003).
Competitors idling	# of competitors' rigs being "stacked" in month t		x	Peers drilling decisions can motivate imitation (Decaire et al., 2020).
Rig level				
Idling-reactivation experience	# of times that a rig has been previously idled and reactivated		x	Frequent idling and reactivation help build and maintain specialized routines (Garud & Nayyar, 1994; Nelson & Winter, 1982)
Rig revenue	A rig's average daily payment rate when under contract (in hundreds of thousands of dollars)		x	Valuable rigs are less likely to be idled (Corts, 2008)
Rig active (0/1)	Focal rig is currently active		x	A rig that is already stacked is more likely to be stacked (Corts, 2008).
Rig experience	# of wells previously drilled by the focal rig		x	Crews become more efficient through learning-by-doing (Kellogg, 2011).

Table 2a: Summary Statistics and Correlations for Capability Erosion Analysis

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Capabilities	1.00											
2. Extent of idling	-0.28	1.00										
3. Firm size	0.06	0.12	1.00									
4. Firm age	-0.10	0.11	-0.06	1.00								
5. Number of clients	0.15	-0.27	0.24	0.18	1.00							
6. Abandoned rigs	-0.07	-0.16	0.16	0.11	-0.09	1.00						
7. Field experience	0.28	-0.31	0.09	0.05	0.17	0.08	1.00					
8. Prior task complexity	0.20	-0.08	0.36	0.16	0.18	-0.05	0.18	1.00				
9. Environmental munificence	0.12	-0.13	0.16	0.04	0.22	-0.38	0.06	0.05	1.00			
10. Resource heterogeneity	-0.08	-0.15	0.14	0.21	0.15	-0.07	0.11	0.15	0.08	1.00		
11. Technological sophistication	0.19	-0.12	0.18	-0.04	0.11	-0.08	0.22	0.17	0.10	0.07	1.00	
12. Human capital reliance	0.09	-0.15	-0.11	0.07	0.05	0.04	0.09	0.18	-0.03	0.14	0.08	1.00
Mean	0.86	0.16	18.45	10.1	12.18	0.06	15.16	0.15	0.16	8.24	0.18	0.72
Standard deviation (S.D.)	6.51	0.22	15.39	9.61	4.51	0.03	7.21	0.09	0.12	2.53	0.10	0.21
VIF (mean VIF = 2.32)	1.56	1.73	1.81	2.32	1.86	2.35	1.77	1.92	2.23	2.63	3.51	2.38

Table 2b: Summary Statistics and Correlations for Idling Choice Analysis

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Idling	1.00																	
2. Demand uncertainty	-0.18	1.00																
3. Capabilities	-0.29	0.03	1.00															
4. Human capital reliance	-0.32	0.01	0.16	1.00														
5. Firm size	0.11	-0.02	0.04	-0.12	1.00													
6. Firm age	0.09	-0.04	-0.11	0.08	0.09	1.00												
7. Resource heterogeneity	-0.21	-0.03	-0.05	0.16	0.10	0.12	1.00											
8. Tech. sophistication	-0.13	-0.02	0.26	0.06	0.18	-0.06	0.12	1.00										
9. Idling-reactivation exper.	0.16	0.04	0.06	0.08	0.12	0.19	0.05	-0.09	1.00									
10. Number of clients	-0.18	-0.13	0.05	0.07	0.14	0.12	0.32	0.03	0.04	1.00								
11. Rig revenue	-0.15	-0.06	0.14	-0.09	0.06	0.07	0.03	0.02	-0.13	0.14	1.00							
12. Rig active	-0.08	0.05	0.09	-0.02	0.04	0.03	-0.04	0.13	-0.08	0.18	-0.03	1.00						
13. Rig experience	-0.10	-0.04	0.04	0.07	-0.06	0.05	0.24	0.09	-0.04	0.07	0.06	0.15	1.00					
14. Other rigs already idled	-0.13	-0.07	-0.03	0.01	-0.01	-0.03	-0.06	0.03	-0.08	-0.08	0.02	0.03	0.10	1.00				
15. Other rigs revenue	0.06	-0.04	0.08	0.02	0.03	0.01	0.02	0.05	0.11	0.04	0.05	-0.06	-0.03	-0.03	1.00			
16. Competitive density	-0.08	0.03	0.06	-0.08	0.08	0.03	0.25	0.13	-0.13	-0.11	-0.03	0.07	-0.04	-0.07	-0.14	1.00		
17. Competitors idling	0.11	-0.16	0.03	0.02	-0.01	-0.02	0.04	0.05	0.15	0.17	0.04	-0.08	-0.02	0.05	-0.06	-0.13	1.00	
18. Env munificence	-0.21	-0.06	0.05	-0.07	0.09	0.06	0.02	0.04	-0.28	0.31	0.12	0.33	0.20	-0.08	0.19	0.20	-0.15	1.00
Mean	0.23	0.31	0.86	0.72	18.45	10.1	8.24	0.18	3.95	12.18	188.2	0.68	18.85	0.13	190.30	32.49	29.46	0.16
Standard deviation (S.D.)	0.15	0.22	6.51	0.21	15.39	9.61	2.53	0.10	2.63	4.51	155.5	0.29	10.62	0.09	162.33	17.35	19.94	0.12
VIF (mean VIF = 2.59)	1.79	3.83	2.12	3.19	1.93	3.13	2.43	1.82	2.73	2.64	1.53	3.15	2.31	1.49	3.15	2.84	3.32	2.10

Table 3: Determinants of Capability Erosion (Hypothesis 1)

DV: Driller's Capabilities	Model 1		Model 2	
Constant	16.125	*(.143)*	15.532	*(.133)*
	(11.022)		(10.657)	
Firm size	0.045	*(.175)*	0.026	*(.186)*
	(.033)		(.020)	
Firm age	-0.121	*(.251)*	-0.109	*(.237)*
	(.106)		(.092)	
Number of clients	1.267	*(.052)*	1.216	*(.054)*
	(.651)		(.631)	
Abandoned rigs	-3.742	*(.210)*	-2.607	*(.235)*
	(2.985)		(2.197)	
Field experience	0.082	*(.034)*	0.078	*(.036)*
	(0.039)		(0.037)	
Prior task complexity	0.664	*(.022)*	0.603	*(.021)*
	(.290)		(.261)	
Environment munificence	1.631	*(.066)*	1.501	*(.060)*
	(.886)		(.798)	
Resource heterogeneity	-0.396	*(.153)*	-0.380	*(.158)*
	0.277		(.269)	
Technological sophistication	2.012	*(.048)*	1.952	*(.050)*
	(1.018)		(.997)	
Human capital reliance	0.166	*(.188)*	0.134	*(.193)*
	(.126)		(.103)	
Predictors:				
Extent of idling			-9.522	*(.005)*
			(3.365)	
Firm Fixed Effect	Yes		Yes	
Adj. R-squared	0.108		0.110	
N	1,836		1,836	

Note: Outcome of interest is the focal driller's capabilities at year t+1. In column 2, the main predictor is the focal driller's extent of idling at year t. The unit of analysis is firm-year. The standard errors are reported in parentheses below the coefficients and clustered by firm. The p-values are reported in parentheses to the right of each coefficient.

Table 4: Treatment Effects Analysis (TEA) (Hypothesis 1)

DV: Driller's Capabilities at *t+1*	PSM	IPW	IPWRA
Treatment (some idling at *t*)	-0.869 *(.005)*	-0.819 *(.009)*	-0.793 *(.007)*
	(.309)	(.308)	(.296)
Control (no idling at *t*)	0.170 *(.129)*	0.197 *(.115)*	0.129 *(.139)*
	(.112)	(.125)	(.087)
Difference	-1.039 *(.013)*	-1.016 *(.015)*	-0.922 *(.019)*
	(.420)	(.418)	(.393)

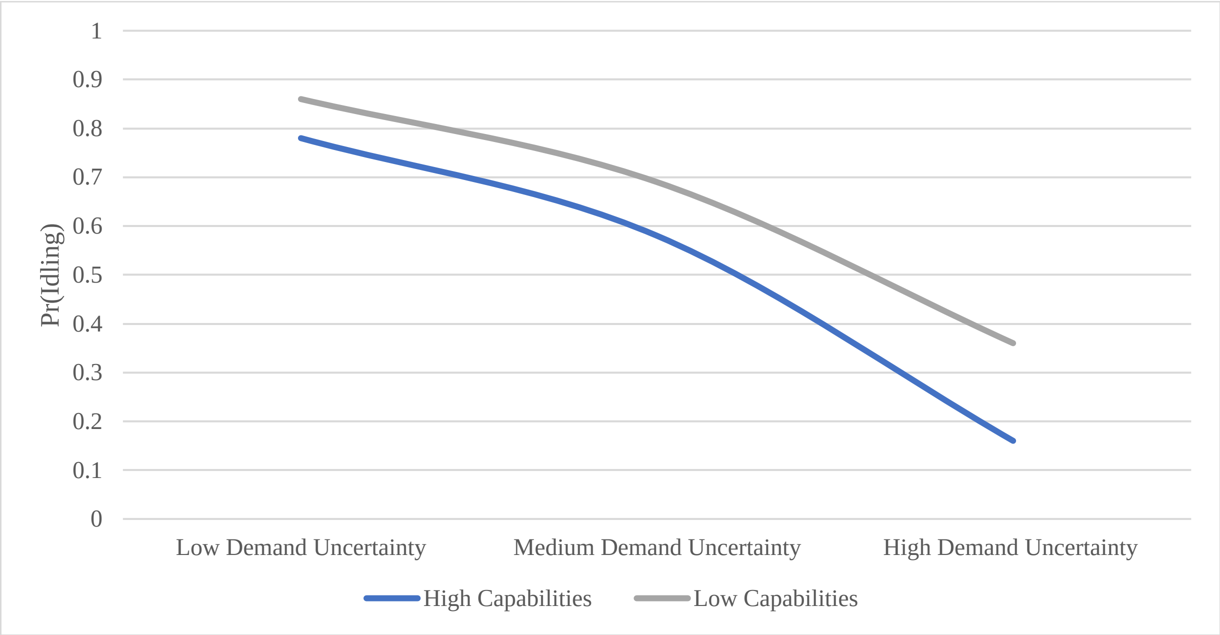
Note: Cases of drillers are matched by their size, age, number of clients, resource heterogeneity, technological sophistication, and human capital reliance. ***Model 1*** uses propensity score matching (PSM). ***Model 2*** uses inverse probability weighting (IPW). ***Model 3*** uses doubly robust estimation (IPWRA). In all three models, covariates appear balanced: 1) using the overidentification test based on the Chi-squared distribution, the null hypothesis that the covariates are balanced cannot be rejected; 2) using the model-adjusted difference in means and ratio of variance between treated and untreated covariates, the differences in weighted means of the covariates are very small and the variance ratios are very close to 1. ***Treatment*** is whether the drillers idled some of their rigs at year *t*. The corresponding control group includes drillers that did not idle any of their rigs at year *t*. For all the models, the outcome of interest is the driller's capabilities at year *t+1*.

Table 5: Determinants of the Likelihood of Idling (Hypotheses 2, 3 and 4)

DV: Idling (0/1)	Model 1		Model 2		Model 3		Model 4	
Constant	3.105	*(.107)*	2.815	*(.118)*	2.212	*(.121)*	2.172	*(.124)*
	(1.928)		(1.801)		(1.425)		(1.414)	
Firm size	0.011	*(.059)*	0.008	*(.060)*	0.006	*(.068)*	0.007	*(.058)*
	(.006)		(.004)		(.004)		(.003)	
Firm age	0.055	*(.124)*	0.027	*(.132)*	0.016	*(.138)*	0.018	*(.140)*
	(.036)		(.018)		(.011)		(.012)	
Number of clients	-0.017	*(.079)*	-0.0098	*(.083)*	-0.0093	*(.087)*	-0.009	*(.090)*
	(.010)		(.006)		(.005)		(.005)	
Resource heterogeneity	-0.004	*(.049)*	-0.003	*(.055)*	-0.002	*(.058)*	-0.001	*(.069)*
	(.002)		(.002)		(.001)		(.001)	
Technological sophistication	-1.298	*(.031)*	-1.091	*(.037)*	-1.073	*(.039)*	-1.054	*(.042)*
	(.603)		(.523)		(.519)		(.518)	
Environmental munificence	-0.662	*(.019)*	-0.347	*(.015)*	-0.334	*(.016)*	-0.324	*(.017)*
	(.281)		(.142)		(.138)		(.135)	
Idling-reactivation experience	0.022	*(.016)*	0.018	*(.011)*	0.017	*(.021)*	0.016	*(.026)*
	(.009)		(.007)		(.008)		(.007)	
Rig revenue	-0.006	*(.029)*	-0.005	*(.026)*	-0.004	*(.033)*	-0.003	*(.028)*
	(.003)		(.002)		(.002)		(.002)	
Rig active	-0.027	*(.003)*	-0.022	*(.008)*	-0.021	*(.005)*	-0.019	*(.011)*
	(.009)		(.008)		(.007)		(.008)	
Rig experience	-0.042	*(.188)*	-0.038	*(.197)*	-0.037	*(.201)*	-0.036	*(.206)*
	(.032)		(.030)		(.029)		(.028)	
Other rigs already idled	-0.156	*(.059)*	-0.124	*(.040)*	-0.112	*(.070)*	-0.110	*(.073)*
	(.083)		(.060)		(.062)		(.061)	
Other rigs revenue	0.004	*(.167)*	0.002	*(.173)*	0.001	*(.193)*	0.002	*(.226)*
	(.003)		(.001)		(.001)		(.002)	
Competitive density	-0.018	*(.235)*	-0.015	*(.257)*	-0.014	*(.253)*	-0.013	*(.273)*
	(.015)		(.013)		(.013)		(.012)	
Competitors idling	0.027	*(.528)*	0.021	*(.557)*	0.019	*(.597)*	0.018	*(.582)*
	(.042)		(.036)		(.035)		(.033)	
Predictors:								
Demand uncertainty			-6.581	*(.008)*	-5.154	*(.010)*	-4.929	*(.012)*
			(2.489)		(2.010)		(1.951)	
Firm capabilities					-0.025	*(.006)*		
					(.009)			
Demand uncertainty × Firm capabilities					-0.002	*(.026)*		
					(.001)			
Human capital reliance							-0.156	*(.022)*
							(0.069)	
Demand uncertainty × Human capital reliance							-0.812	*(.039)*
							(.393)	
Firm Fixed Effects	Yes		Yes		Yes		Yes	
Pseudo R-squared	0.166		0.168		0.175		0.178	
N	176,256		176,256		176,256		176,256	

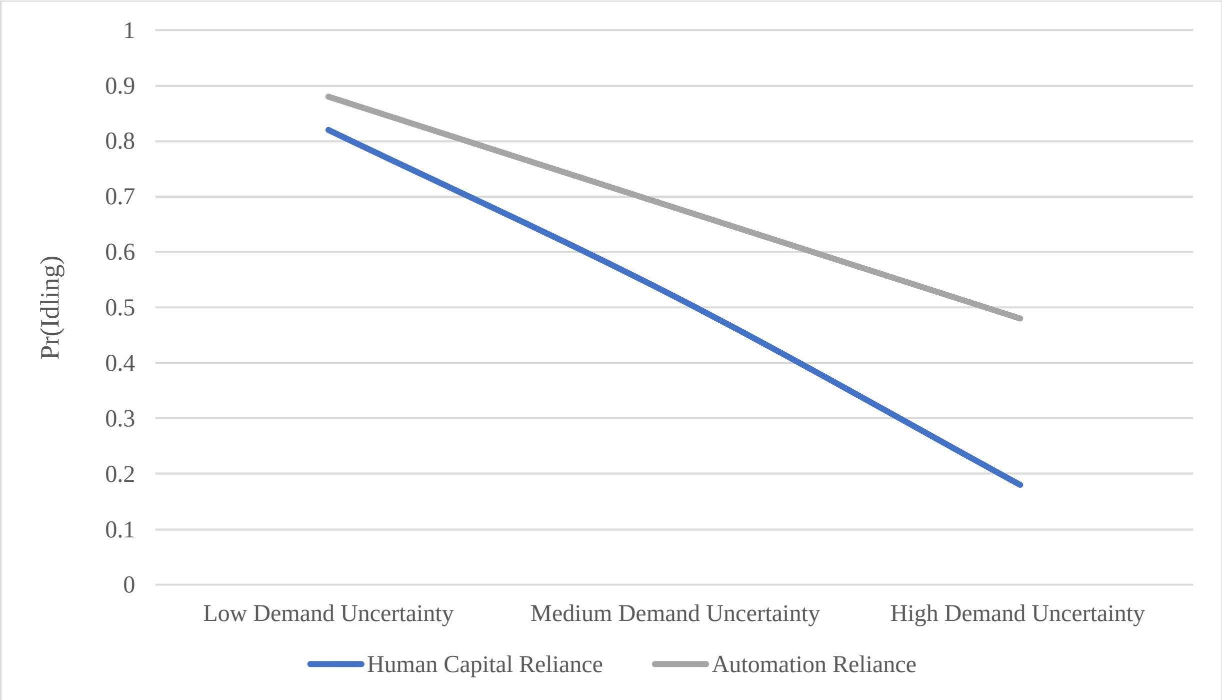
Note: The outcome of interest is whether a driller's rig is idled (=1) or not (=0) at month *t*. We estimate using the logit model. The unit of analysis is at the driller's rig-month level. The standard errors are in parentheses below the coefficients and clustered by firm. The *p*-values are reported in parentheses to the right of each coefficient.

Figure 1: Marginal Effects of Demand Uncertainty for High and Low Capability Drillers on the Predicted Likelihood of Idling



Note: We characterized 'high' capability drillers as those having instrinsic drilling speeds 1 S.D. above the mean, and 'low' capability drillers as those having instrinsic drilling speeds 1 S.D. below the mean.

Figure 2: Marginal Effects of Demand Uncertainty for a Driller's Rig Being Fully Reliant on Human Capital and Being Automated on the Predicted Likelihood of Idling



Note: We characterized drillers relying on human capital as those drillers whose focal rig is traditional fully-human operated, and those relying on automation as those whose focal rig is automated.

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