Knowledge search and learning in sustainability practices

Invited papers

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Abstract

Framing of the research: *How do organizations solve problems of environmental sustainability? As organizations search for ways to resolve issues involving the natural environment, they can learn to improve their performance. The rate and extent of their learning and performance improvement are contingent on several factors.*

Purpose of the paper: *This review studies the links between search activities as they apply to problem solving, and sustainable outcomes. Its goal is to examine the existing research on this topic and better clarify the role that business organizations play in creating and solving problems that affect the natural environment.*

Methodology: *This is a literature review of management and strategy papers on the topic of search activities in the context of sustainability.*

Results*: Overall, the review suggests one mode of resolving environmental problems: searching narrowly to resolve routine operational problems while experimenting and adding breadth to search activities over time. The combination of a focused search in any one time period with experimentation via breadth over time periods balances the need for operational efficiency with learning to yield the greatest improvements in environmental performance.*

Research limitations: *As this is a literature review, it does include any novel empirical research.*

Managerial implications: *The findings inform managers about when to expand search breadth versus when to search more narrowly. As this review focuses on environmental issues, the results are also valuable for policymakers.*

Originality of the paper: *This literature review of search activities in the context of sustainability integrates findings across multiple papers to highlight common implications for research, policy, and practice.*

Key words: search; learning; sustainability; problems; environmental; performance

1. Introduction

How do organizations search to solve problems with relevant consequences for the natural environment (Ashford and Heaton, 1983; Berchicci *et al.*, 2019; Caner *et al.*, 2017; Dutt, 2013; Dutt and Mitchell, 2020)? And what role do knowledge creation activities play in enabling these search activities (Dutt and Lawrence, 2021; Katila, 2002; Katila and Ahuja, 2002; von Krogh, 1998; Lampert and Semadeni, 2010; Nonaka *et al.*, 2006; Rosenkopf and Nerkar, 2001; Williams, 2007)? Grand environmental challenges are prevalent across different geographies and industries (George *et al.*, 2016). As management scholars, we need to better understand the role that business organizations play in creating and resolving these problems. Moreover, while there is substantial research on how organizations search and solve problems, only a subset of this research links organizations' choices and activities to issues of environmental sustainability. Thus, the goal of this review is to examine the existing research on this topic and better clarify the role that business organizations play in creating and solving problems that affect the natural environment (Dutt and Mitchell, 2020; King, 2007; Lyon *et al.*, 2018).

Empirical research on environmental issues suggests that win-win solutions are rare (Dutt and Lawrence, 2021; King and Lenox, 2000; Lyneis and Sterman, 2016). Instead, organizations must make tradeoffs between investing resources to gain the knowledge needed to solve environmental problems and balancing their costs. In turn, some reductions in financial performance may be necessary for firms to improve sustainable outcomes (Bocken and Geradts, 2020; Busch *et al.*, 2020; Christ *et al.*, 2017). Because these types of actions taken by firms directly influence the natural world, it is vital to study business organizations' activities in environmentally relevant contexts. To understand the types of tradeoffs necessary for business organizations to address environmental sustainability issues, we examine studies across two contexts.

2. Toxic waste studies

We start by examining a series of studies on the toxic waste management activities of manufacturing facilities. Since 1987, the United States (U.S.) Environmental Protection Agency (EPA) has been tracking the waste management and disposal activities of the vast majority of U.S. manufacturing facilities in a database called the Toxics Release Inventory (TRI) (EPA, 1996, 2011; King, 1995). While reporting all activities to the TRI is mandatory, the goal has been to push facilities to track, document, and disclose their waste management activities (Karkkainen, 2000; Neumann, 1998; Patten, 1998; Stockwell *et al.*, 1993). This information has been used to help facilities improve waste management and develop best practices. Toxic waste has a high financial and regulatory cost in the U.S. In turn, a combination of regulatory and cost-based pressures has induced manufacturing facilities to reduce their toxic waste output. Over the last twenty years, toxic waste output in the U.S. has reduced substantially. It is possible that some of this output is a function of firms shifting manufacturing outside the U.S. (the data in this study is limited to the U.S.) (Berry, Kaul, and Lee, 2021; Li and Zhou, 2017). Some additional changes can be attributed to improvements in technology (Karimi Takalo *et al.*, 2021; Kemp, 2000; Schiederig *et al.*, 2012). Yet, the persistent heterogeneity in waste reduction, even when comparing facilities in the same industry treating waste generated from the same toxic chemical, suggests that at least some portion of the improvement is attributable to deliberate choices to reduce waste. I will focus on several studies that clarify the search and learning activities that underly the observed improvement in environmental performance.

Andrew A. King has produced a mountain of research on this topic, beginning with his dissertation and continuing in follow-up work with coauthors (Berchicci and King, 2007; King, 1995, 1999; King and Toffel, 2007; King and Lenox, 2001a). Dutt and King (2014) explores whether different types of waste reduction activities reduce waste differently and, if so, why. Facilities can either use end-of-pipe (EOP) techniques to reduce toxic waste or dispose of waste without intervention. The study found that facilities using EOP techniques report an initial growth in waste followed by persistent reduction. By receiving regular feedback about their actions' outcomes, these facilities appeared to be improving relative to matched facilities not using EOP techniques.

This finding supports learning theories about the benefits of codification and feedback (Adler and Clark, 1991; Di Stefano *et al.*, 2016; Edmondson *et al.*, 2003; Pisano, 1996; Zollo and Winter, 2002). While this result is relatively straightforward from the perspective of management research, it contradicts prior wisdom about EOP techniques impeding waste reduction. Policymakers have argued that by allowing facilities to fix their mistakes, EOP techniques indirectly promote waste formation. Instead, for the average facility, the learning benefits outweigh incentive problems and using EOP treatment associates with reduced waste. The disposal and creation of toxic waste is costly for firms, and reducing its output is thus beneficial to their financial performance. Relatedly, toxic waste is an undesirable byproduct in general for society. Regulators would therefore also like to see firms reduce its output. Given these aligned incentives, it is not surprising that organizations want to reduce waste and find ways to do so.

Yet, there is heterogeneity in how much different facilities are able to reduce waste. A fundamental choice that facilities have in this context is between continuing ongoing waste reduction techniques and experimenting with new techniques, in any given year. Continuing with ongoing techniques, either those that have been used to manage the focal chemical or those that have been used to manage another chemical in the facility can help improve their efficiency, making waste reduction more successful. On the other hand, experimenting with a new technique requires the facility to learn something new. In the process of learning how to use this new technique, there may be some inefficiencies in waste reduction. However, over time, we would expect more learning to result from a strategy that values experimentation over efficiency some of the time (Bandura, 1965; Dutt and Lawrence, 2021; Leiponen and Helfat, 2010a; Payne *et al.*, 1988).

3. Learning, breadth, and operational performance

These findings support the idea that long-term learning requires some experimentation (Rockart and Dutt, 2015; Rockart and Wilson, 2019; Stan and Vermeulen, 2012). While experimenting with new waste reduction techniques is associated with a slight increase in waste output in the following year, over time these facilities perform better with regards to waste reduction. Specifically, these facilities are on a steeper waste reduction trajectory, while controlling for all fixed factors at the facility-chemical level. These effects also hold for facilities experimenting with new techniques for other chemicals within the facility. Thus, while adding new knowledge to the facility's knowledge stock incurs a cost in terms of increasing waste in the following year, over time, this new knowledge helps the facility reduce waste to a much greater extent.

A fundamental contribution of this paper is to carefully measure the breadth of waste reduction in any year. While the context of this study is generalizable to manufacturing facilities and other similar operations settings, the basic findings resonate with other contexts that consider how knowledge search influences sustainable outcomes. Fundamentally, the breadth of search influences organizational performance differently over time. A narrower search is associated with better operational performance metrics in the short term. On the other hand, greater breadth appears to be critical to knowledge generation and learning and is associated with better waste management outcomes in the longer term. These results clarify which approaches are beneficial for organizations based on their level of experience, as well as these strategies' implications for the natural environment.

A related study (Berchicci *et al.*, 2019) explores the benefits of different numbers of waste reduction activities. The EPA touts one set of activities-those designed to reduce waste at the source-as the ideal way to manage waste. These source reduction activities push facilities to use cleaner input materials and refine their waste management processes such that the entire production process is improved (De Young *et al.*, 1993; Lober, 1996; Popkin, 1989). While this method has clear advantages, the reality is that facilities need an extensive understanding of waste management before such improvements at the source can be implemented. In turn, while a large number of facilities implement these interventions, the share of facilities implementing source reduction activities is only about ten percent of the sample (Berchicci *et al.*, 2019).

In order to implement these source reduction activities, facilities collect suggestions from employees, managers, suppliers, vendors, and others before choosing to implement new practices. On average, Berchicci *et al.*, (2019) show that facilities using techniques to reduce waste at the source performed better, i.e., reduced waste by a greater amount over time relative to a control sample of facilities that do not reduce waste at the source. However, it is worth recognizing the limits to a causal interpretation of this result.

There is a substantial selection effect underlying the facilities that choose to search across different knowledge sources and implement source reduction activities. The matching techniques used in this analysis rely on observable differences across facilities. Thus, to the extent that underlying differences in preferences are not captured by observable differences, the control sample may not be very reliable. Theoretically the EPA may be correct in that assuming source reduction activities are the best way to reduce waste (De Young *et al.*, 1993; Lober, 1996; Popkin, 1989). However, empirically it is difficult to assess how much waste reduction arises from source reduction activities versus other unobserved differences between the two samples of facilities.

The first-order finding in this research is that searching through knowledge sources to reduce waste at the source appears to be beneficial for waste reduction. Specifically, this paper asks the question: How much of the heterogeneity in waste reduction is explained by additional variation in search for source reduction? A baseline expectation in the technological search literature is that using a higher number of knowledge sources benefits search outcomes (Foss *et al.*, 2013; Laursen, 2012; Leiponen and Helfat, 2010a, 2010b; Leonard-Barton, 1995). Facilities can use between one and eight knowledge sources to identify techniques to reduce waste. A greater number of knowledge sources (higher search breadth) is especially beneficial when organizations are developing new knowledge. However, in operational contexts, where organizations are improving ongoing activities rather than generating new knowledge, the net benefits of breadth are less clear. This is because the costs of search are substantial. This study revealed that using more than one knowledge source in one year is associated with a performance reduction. In other words, engaging in source reduction appears to aid waste reduction. However, using multiple knowledge sources in source reduction seems to be as costly as using none. Furthermore, facilities focusing on a single source in one year and changing the source across years appear to reduce the most waste. These findings illustrate the benefits of a focused waste reduction strategy that adds breadth over time: This is the approach that allows facilities to reduce waste to the greatest extent (Berchicci *et al.*, 2019).

4. Tradeoffs for sustainability

By and large, these studies focus on outlining and quantifying the tradeoffs inherent to search in the context of sustainability. Much of this research is contrary to a stream of management that has focused instead on the presence of win-win opportunities for sustainability (Ahuja and Hart, 1996; Elkington, 1994; Porter and van der Linde, 1995). While these win-win opportunities may exist, a search strategy that focuses on a narrow set of solutions may not be in the best interest of either individual firms that aim to improve their sustainable capabilities or the policymakers that would like to reduce dependence on non-renewable technologies, for instance. A more wholistic search strategy that recognizes the presence several types of solutions to sustainability challenges is more realistic (Dutt and Joseph, 2019; Hoffmann *et al.*, 2009; MacDuffie, 1995). The acceptance of tradeoffs is more likely to encourage firms to make changes and accept some short-term reductions in performance (Bocken and Geradts, 2020; Christ *et al.*, 2017; Kleindorfer *et al.*, 2005).

A better understanding of tradeoffs will also enable analysts and investors to recognize that short-term drops or a leveling off in performance is not a sign of a weak company but rather of a firm that can see the value of long-term investments. Recent work focusing on the time horizon of investment is essential to understanding the unique types of challenges that arise in settings relevant to understanding sustainable outcomes (Ortiz-de-Mandojana and Bansal, 2016; Slawinski and Bansal, 2012; Wang and Bansal, 2012).

In terms of the types of knowledge generating activities that are relevant for sustainability, it is important to consider the role of operational problems (Bromiley and Rau, 2016; King and Lenox, 2001b; Kleindorfer *et al.*, 2005; Vivero, 2002). These routine, ongoing issues such as disruptions on the product line are commonplace not only in business organizations but a wide range of organizations such as hospitals, and manufacturing facilities. When it comes to triggering organizational learning for sustainability, their frequent appearance creates ongoing learning opportunities. Additionally, the consequences of not addressing these problems can be particularly adverse for the natural environment. In the case of toxic waste reduction, the most viable way for production facilities to solve operational problems is to focus their search within a specific period, seeking knowledge from a narrow range of sources. As they gain waste management experience, facilities can expand their breadth of knowledge by searching a broader set of sources to continue learning over a longer time period. Given the comprehensive nature of the sample, these findings are likely to be relevant when considering other settings with routine operational problems. The relevant managerial takeaway here is to balance the old with the new: focused search within a time period-with increasing breadth by trying new techniques over time. Organizations should balance the need for new knowledge while exploiting what they already know and aim to improve sustainable outcomes slowly.

These findings have implications for theory and practice. First, the study illustrated that the magnitude and scope of learning benefits are substantial in operational contexts. Second, it showed how a focused problem-solving approach appears to reduce waste to the greatest extent. This finding holds whether considering activities at the source of production or after the waste has been produced. Last, this study showed how experienced organizations continue to improve their operational performance. When it comes to environmental issues, we might have expected organizations to settle for the low-hanging fruit and then stagnate. In contrast, we found that experienced organizations continue to improve, and learning plays a significant role in this improvement.

For practitioners and policymakers, this research highlights the benefits of structural interventions that aid learning. The EPA's TRI program is just such an intervention and appears to have meaningfully supported learning. By documenting and codifying toxic waste output and all search activities, the EPA has created an ecosystem where facilities can learn.

5. Renewable electricity

To understand the extent to which these findings might translate to a different setting, I examine a series of papers on firms' search activities in the renewable electricity niche of the U.S. Electricity industry. The U.S. Electricity industry predominantly comprises large, publicly listed firms (e.g., Duke Energy) that generate and distribute electricity but typically do not develop the technology needed to do so themselves. The operational and business side of this industry-for instance, retail prices-is largely regulated by state governments (except for 16 states that are deregulated). Yet R&D activities are regulated by the federal government (Costello, 2016), to which firms report detailed accounts of their R&D spending. Such R&D spending activities include both internal investments and investments in external partnerships, including with universities and non-profits. This is an important setting to examine because the choices of utilities firms have a consequential impact on carbon output and climate change. While this industry is polluting, it is also heavily regulated. Thus, the government may be able to push firms to make choices that are beneficial for the natural environment.

Recently, state governments have passed policy mandates to push electric utility firms to adopt new technologies and services. One such set of policies is Renewable Portfolio Standards (RPSs), which require increases in renewable electricity output. RPSs were rolled out across 29 states from 2000 to 2010 (Carley, 2009; Fabrizio, 2012; Fremeth and Marcus, 2011; Lyon and Yin, 2010; Wiser *et al.*, 2007). Although RPSs are broadly similar across states-requiring firms to derive some share of the total electricity they provide from solar, geothermal, biomass, wind, and/or hydro sources by a future date (Carley *et al.*, 2018). For instance, Michigan adopted RPSs in 2008 and required firms operating in the state to provide 15% renewable electricity by 2015. Comparatively, Hawaii adopted RPSs in 2001, setting a target of 10% renewables by 2010, increasing to 30% by 2020 and 100% by 2045[1].

Renewable electricity capacity was low in general in 2000s when RPSs were first rolled out. However, some firms had willingly invested in and generated electricity using renewable technologies before RPSs. In interviews, some of these renewable-investing firms mentioned the value of renewable electricity as representing a new market niche and a growth opportunity (Dutt, 2013). Most suggested their choice to invest in renewables pre-RPS was driven by cost effectiveness. For instance, firms in locations proximate to a major river tended to generate hydroelectricity. This pattern suggests that firms have different existing renewable capabilities when facing RPSs. While the electricity industry is largely regulated at the state level, some aspects can be regulated at the federal level. In particular, there have been several failed attempts at passing a federal RPS. Although the federal law did not pass, they indicated to firms the general importance of this new niche, which could push firms to start searching for knowledge about these new technologies. Thus, there are regulatory pressures at both the federal and state-level that can influence firms' search activities in the renewable electricity niche.

To understand whether these regulations might drive heterogeneity in search, Dutt and Mitchell (2020) distinguishes between these two problem sources. They argue that the state RPSs represent a new problem that is proximate to the firm, and the federal attempts, represent a remote problem. The paper argues that the distance from the problem may influence how

[1] Details at https://programs.dsireusa.org/system/program/detail/606

firms respond to each problem. On the one hand, firms should understand better problems arising from proximate sources, as they may be familiar with the source. They may also expect to be able to communicate with the local problem source and influence it. On the other hand, remote problem sources are likely to be perceived as more challenging; the problems posed by them may be more likely to push firms to search. Thus, problems raised by proximate sources should appear easier to manage relative to similar problems raised by remote sources.

Examining whether and how the source of the problem relates to the breadth of a firm's search activities allows us to assess whether firms respond to similar problems in different ways based on the problem source. The results suggest that a firm's search breadth depends on the problem source. Remote problems have a stronger impact on search, but this action is moderated by technological capabilities, in this case the ability to generate renewable electricity. This result uncovers an important factor driving heterogeneity in search that can allow managers and practitioners to direct firm actions more effectively. Moreover, it suggests that policymakers should consider accounting for experience when designing environmental policies.

These differences in technical expertise and relevant capabilities appear critical to search activities in new niches. This have been illustrated in several studies of new market entry across a range of industries (Agarwal and Helfat, 2009; Agarwal *et al.*, 2017; Chen *et al.*, 2012; Furr and Kapoor, 2018; Helfat and Lieberman, 2002; Holbrook *et al.*, 2000; Moeen, 2017) as well in the development of markets for technology (Arora and Gambardella, 1994, 2010). The question remains: Do such capabilities also apply in contexts of environmental significance? A recent paper examines external search for technological and regulatory knowledge by firms in the electricity industry (Dutt and Cunningham, 2020). Similar to other work on this setting (Carley *et al.*, 2018; Fremeth and Marcus, 2011; Lyon and Yin, 2010), it uses variation in the RPSs as a trigger for external search. The results suggest that indeed, firms with technical expertise in the form of renewable capabilities tend to search more externally. These firms are more responsive to the law even though they already possess some capabilities to meet the requirements of the mandates. While these firms are searching for technological knowledge, they are also searching for knowledge about the policies and regulatory changes. This suggests that their experience also influences search breadth positively. While less capable firms eventually start searching, they start much later than the capable firms and search more narrowly with regards to the types of knowledge they seek.

This result is particularly consequential to understanding how to push firms towards sustainable outcomes. A naïve view on regulatory effectiveness might suggest that the mere presence of a regulation may be sufficient to push firms to change their behaviors. The reality is that designing regulations that can effectively change firm behavior is both difficult and costly (Acemoglu and Finkelstein, 2008; Blind, 2016). When successful, regulations can push firms to engage in behavior that improves consumer and societal outcomes while raising the standard across the industry. For instance, in the pharmaceutical industry, a regulatory change proposed by Ridley, Grabowski, and Moe (2006) led to the passage of a law designed to push firms to create drugs for orphan diseases and increased related drug approvals (Gans and Ridley, 2013).

However, such regulatory success doesn't come about easily. While RPSs have been instrumental in changing the costs and benefits of renewable generation, they have not been uniformly successful. Energy policy research has shown that the stringency or the strictness of the regulation is an essential predictor of firms actually changing their behavior. Important research done by Carley and coauthors (Carley *et al.*, 2018; Carley and Miller, 2012) shows that regulatory stringency, which measures the strictness of the RPS regulation in terms of both the size of the change required and the time until compliance is the best measure of regulatory effectiveness in this setting. This measure starts by measuring the gap between the target and existing renewable base at the state level, with a larger gap being more stringent. Accounting for the existing installed base is important for measuring stringency (Wiser *et al.*, 2007). For example, while California's RPSs originally targeted 20% renewable electricity, its installed base at the time already exceeded 20%. Thus, while the target was higher than in several other states, the regulation was less stringent than for a state with a lower installed base. The second dimension of regulatory stringency is time to achieve compliance. A date that is more proximate is more stringent as it forces firms to more quickly invest in new technology. Some research has examined these two dimensions of stringency (the gap between target and installed base (Lyon and Yin, 2010; Yin and Powers, 2010) and time to compliance (Dutt and Joseph, 2019)) separately. However, considering these factors jointly using Carley *et al.* (2018)'s state of the art regulatory stringency measure provides a more comprehensive understanding of when and how firms might change their behaviours in this context.

The second factor to consider is heterogeneity in firms' expertise, i.e., their capabilities (Arora and Gambardella, 1994; Berchicci *et al.*, 2012; Capron and Mitchell, 1998; Helfat *et al.*, 2007; Helfat and Lieberman, 2002; Moeen, 2017; Rockart and Dutt, 2015). Building upon prior work that has shown capable firms to be more proactive in responding to new challenges, we would expect that when it comes to sustainability-related challenges, capable firms would be the first responders. While these firms have some baseline knowledge, they also have more to gain from gaining additional expertise with this new niche (Arora *et al.*, 2018). In response to these regulations, all firms acquired some external knowledge through research and development (R&D) investments in outside businesses and institutions (Costello, 2016). A few firms also invested in internal R&D. Furthermore, while all firms searched for knowledge about regulations, policies, and other "non-market" activities, only experienced firms acquired technological knowledge. However, capable firms acquired substantially more external knowledge, were quicker to respond to the regulatory change, and searched across a wider range of knowledge sources (Dutt and Cunningham, 2020).

These findings highlight several noteworthy trends. First, in a regulated, non-technologically innovative context, firms are more likely to gain external than internal knowledge. Second, the extent to which a firm seeks external knowledge reflects its prior technological capabilities. Given the important role that capabilities play in building the ecosystem in new industries and niches, management scholars and policymakers should account for these differences in how they design new regulations.

6. Conclusions

In general, across both settings, we observe the entwined roles of experience and search breadth in relating to learning in contexts of environmental sustainability. Experienced firms can solve problems and search a broader range of knowledge sources; they also appear to respond to problem sources distinctly. These findings can guide managers in deciding when to pursue breadth. Experienced organizations may not incur high costs from pursuing high breadth. Still, managers of inexperienced organizations should gain experience before expanding their range of search activities. For policymakers, these findings suggest the possible benefits of designing distinct policies for experienced and inexperienced firms as well as in acknowledging that the source of the problem may trigger different search actions. Ultimately, recognizing that firms of different experience levels encounter varying costs and benefits to search breadth should help bring about environmentally sustainable changes more effectively.

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