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# Identifying and measuring dynamic capability using search routines

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**Abstract:** Much attention has been given to the theoretical and empirical difficulties of identifying dynamic capability (DC), given that it is a latent construct that is difficult to observe. There is consensus that DC should be defined so as to distinguish the capability for change from the change achieved: it is the organisation's capacity to change its resource base. But operationalising this idea has proven difficult. We propose an empirical representation based on a modest theoretical extension: the accepted definition implies that DC is constituted in organic engagement with the operating resources it is intended to change. This extension allows us to represent DC using a widely-recognised, observable underpinning of DC, search routines. Using data on Irish manufacturers' efforts to adapt to a heightened environmental-regulation regime, we draw from environmental-management research and the evolutionary and behavioural theories of the firm to specify criteria for identifying, categorising, and measuring search routines, and using this to construct a DC measure. The contribution is to present a replicable, theory-based protocol for studying DC and its complex relationship with firm performance and evolutionary fitness.

**Keywords**: dynamic capabilities, organisational routines, search routines, capabilities, methodology

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## Introduction

The dynamic capability view has become an important research perspective on organisational strategy and change (Teece et al., 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002; Helfat et al., 2007; Teece, 2007; Arend and Bromiley, 2009; Helfat and Peteraf, 2009). For organizations to survive and grow, they must have a superior ability to change their resource base. Teece et al. (1997) proposed the dynamic capability (DC) framework as a means of explaining how firms respond to change through their ability to integrate, build and reconfigure resources and competences. The potential of DC to provide insights into the key strategic question of how to sustain competitiveness in the face of changing environments has generated a high intensity of research activity (Barreto, 2010; Di Stefano et al, 2014; Schilke et al, 2017).

The approach has also received criticism, including doubts about its ability ever to develop into a fully-fledged theory. Much of the criticism is around the difficulty of representing hard-to-observe dynamic capability in empirical research. For the theory to be testable it needs to be able to identify DC empirically without presuming it to exist where strong performance is achieved. Helfat et al. (2007) solved this problem theoretically by defining DC in terms of the firm's ability to change its resource base rather than the competitive results, but subsequent attempts to operationalise their construct have not led to a consensus. It has been argued that empirical DC research still suffers from a thin and disconnected empirical base (Giuduci and Reinmoeller, 2012), poor integration back into theory development (Becker, 2005) and a failure to test and extend the theory in the field (Arend and Bromily, 2009; Grant and Verona, 2015).

This article proposes that observable search routines can be used to create an indicator of DC that is theoretically sound, empirically robust, and conceptually and empirically distinguishable from the performance that DC is thought to effect. Search routines are routinised processes for identifying and implementing new or changed organisational routines at the operating level (Nelson and Winter, 1982). More recent treatments have emphasised the role of search routines in DC (Winter, 2003; Teece, 2007; Helfat et al., 2007; Schilke, 2014). Search routines can be seen as both the constituents (Zollo and Winter, 2002) and the repositories (Becker et al., 2005) of DC, helping to generate new operating capabilities that align the firm with its environment and strategic objectives (Teece et al., 1997).

The key to using search routines as a basis for operationalising the theory of DC is a modest conceptual extension of its definition in Helfat et al. (2007: 4): 'the capacity of an organization to purposefully create, extend, or modify its resource base.' We argue that this definition implies an organic linkage between DC as routine-changing routine and the operating routines it is intended to 'create, extend, or modify.' This small theoretical extension opens the door to a major empirical improvement in our ability not only to identify DC in practice but also to create an ordinal indicator of its strength.

Thus, our research question is as follows: Can we advance the literature by using search routines as the basis for an empirically robust DC indicator that closely links, in observable ways, the routine-changing activities of search with the operating routines that are to be changed?

To explore how studying search routines might reveal the role of dynamic capability in firm adaptation and performance, we investigated the differential responses of companies in two Irish industry sectors to new environmental regulation that required

significant technological and managerial change. We were able to study these responses with the benefit of a substantial research literature on environmental management, including its relationships to organisational capability and change (Hart, 1995; Aragón-Correa and Sharma, 2003; Hofmann et al., 2012), regulatory regime (Porter and van der Linde, 1995), and competitive viability (Wagner et al., 2001). From information provided to the regulator we created a longitudinal dataset on environmental performance; we complemented this with qualitative data on how the changes were made, collected from a subset of case study firms purposively sampled across a range of performance outcomes. Our research design steps back from exploring the link between dynamic capability and sustainable competitive advantage (as in, for example, Arend, 2015). Instead, we focus on the 'evolutionary fitness' that might be attributable to DC – the extent to which it 'enables the firm to make a living' (Helfat et al*.,* 2007: 7) by adapting to changed circumstances – in this case, by fostering environmental-management performance as newly important to controlling regulatory costs and even to survival.

The results suggest that by empirically unpacking the concept of search routines, and showing how these routines work to generate new operating routines that are capable of achieving the firm's new strategic objectives, it is possible to measure DC in a way that helps understand it and its complex link with organisational performance. This kind of search routines-based indicator of DC would thus contribute to increased rigour and coherence in the body of related empirical work, allowing a more fruitful cross-fertilisation between theory and evidence.

The paper proceeds as follows. First, we look further at the dynamic capability concept, the criticisms that have developed in the literature, and the evolutionary and behavioural theories of the firm that provide a robust basis for empirical work

grounded in search routines. Two empirical sections then explain the methodology and research design employed in our study, including what search activities will be studied and how they will be assessed as indicating DC, based on their role in firms' efforts to strengthen and/or create environmental-management capabilities. A discussion section explores the implications of these results for the problems set out here at the start, and we conclude with a summary of the paper's main contributions.

## Literature review

One of the central criticisms of the dynamic capability view has been a lack of precision in defining and operationalizing the DC construct, tied to its inherently intangible nature (Loasby, 1998). Capabilities cannot, by definition, be observed. Indeed, this is part of their power in supporting competitive advantage: their causal ambiguity and tacit nature support their inimitability.

Grant and Verona (2015) examine in more detail how the tacit nature of organisational capabilities in general and dynamic capabilities in particular make it problematic to operationalise the concepts. We identify DC conceptually as latent action (Di Stefano et al., 2014), treating it as a form of unobservable (Godfrey and Hill, 1995) or latent (Hult et al., 2002) construct. The requirement then is to identify observable variables that can be credibly theoretically linked to the latent construct of interest; the construct is formed by these underpinning variables, but is more than simply the sum of those variables (Jarvis et al, 2003). Some studies have relied on the relationship between antecedents of capability - such as experience or resource inputs - with performance, inferring the mediating role of capability, but unless alternative explanations for the relationship between antecedents and performance can be excluded, the credibility of the results remains in question (Grant and Verona, 2015).

As noted in the introduction, this problem was solved at the conceptual level by Helfat et al. (2007: 4): DC is 'the capacity of an organization to purposefully create, extend, or modify its resource base'. By avoiding any presumption of effectiveness in boosting performance, this definition allows for a distinction in principle between possession of the capability and the observation of a successful outcome, thus meeting in principle earlier arguments that in practice DC is defined tautologically (Williamson, 1999; Zahra et al., 2006). Helfat and colleagues' approach draws attention instead to resource base-changing processes, which conceivably might be observed for analysis and testing of the concept. Although this proposition has been widely accepted in theory (Peteraf et al., 2013; Di Stefano et al., 2014), its operationalisation has been slow.

A few empirical researchers have proposed getting at DC through observable, routinised processes of organisational search. Amid a proliferation of definitions (Barreto, 2010), there is broad agreement that DC is founded in *recurrent patterns* of activity aimed at identifying, evaluating and implementing change in the organization (Giudiuci and Reinmoeller, 2015). Following Zollo and Winter (2002) and Schilke (2014), we identify such search routines as a strategic lens through which to study DC. To pursue this, we turn to one of the roots of the dynamic capability view, the evolutionary economic theory of the firm, and its antecedent, the behavioural theory of the firm.

In evolutionary economics the central unit of analysis is the routine, defined as 'all regular and predictable behaviour patterns' (Nelson and Winter, 1982: 14) that function as durable storage for tacit knowledge, allowing for the preservation of knowledge as well as its effective use. Routines are generally accepted to be a key

building block of capability (Nelson and Winter, 1982; Teece et al., 1997; Dosi et al., 2000; Eisenhardt and Martin, 2000; Winter, 2003; Helfat et al., 2007).

Nelson and Winter (1982) identify three types of routine. The first two are those routines that govern the short-run operating activity of the firm and routines for standard adjustments to operating activity in response to external conditions. In both these cases the outcome of performing the routine is known. They also identify a third type of routine, where the process is routinised but the outcome is not: 'the relatively constant dispositions and strategic heuristics that shape the approach of the firm to the non-routine problems it faces' (14). Nelson and Winter describe these as search routines, defined as 'the patterning of particular ways of attempting to innovate' (133) and 'routine-guided, routine changing processes' (18). Routines are seen as always specific to their purpose, and the idea of a general problem-solving routine is explicitly discounted (Winter, 2003). Search routines may be found either as organisational functions aimed at learning and change in a particular area, for example R&D or market analysis, or as procedures that are invoked in response to a need for review of a particular kind of problem, when the routines might be of the form: 'given a problem, direct a subordinate to look into it – or appoint a committee or a task force, or bring in a consultant with a good reputation' (Nelson and Winter, 1982: 132). These kinds of routines allow the firm to change: 'through the joint action of search and selection, the firms evolve over time' (19).

In focusing on both search and selection, Nelson and Winter draw directly on the behavioural theory of the firm associated with Cyert and March (1963, 1992) (on this lineage, see Augier and Teece, 2008). Organisations face bounded rationality and imperfect information. Rather than optimising, firms take satisficing decisions according to heuristics and rules of thumb. Rules evolve over time, so act as carriers

of prior experience and learning. Higher-level rules guide the modification of lower level rules, often prompted by failure of an existing rule (Cyert and March, 1963). Cyert and March, following Simon (1955), approach search as involving the creation of potential new solutions, not just the discovery of pre-existing sets of alternatives. When a solution is deemed satisfactory, search stops and the new solution becomes fixed as a routinised process or rule. Evolutionary theorists have significantly developed this theme, positing for example that a set of potential solutions typically can only be assessed/selected in an experiential manner (Gavetti and Levinthal, 2000) through real world trials of proposed solutions (Winter, 2000).

Evolutionary theorists also draw on behavioural theory's emphasis on organisational goals and aspirations in this context. Goal setting is seen as part of search, used to frame the problem to be solved (Nelson and Winter, 1982), and also in establishing aspirations which motivate the search activity, such as routines for benchmarking (Winter, 2000). But behavioural theory has more to say here. One of its tenets is that change processes within firms reflect the 'coalitions' of groups and interests that are important in their management (Cyert and March, 1963). Different coalition members may be guided by divergent aspirations and hence push for different goals as the organisation navigates the need to change and adapt to shifting competitive conditions. Which goals become most salient depends on the closeness of various coalition members to the 'decision neighborhood' of the change processes (Augier and Teece, 2008: 1191). In a setting like ours, relations with external stakeholders like the environmental regulator (and potentially local authorities) can play a role in shaping the direction and efficacy of search and the strength of dynamic capability. Conversely, as internal coalition members, managers with access to decision levers

can block search from creating potential new rules or routines that might destabilise existing 'organisational codes' (March, 1991: 85).

'Search' therefore encompasses search, assessment, selection and implementation of new ways of doing things. This corresponds directly to the theorised functions of DC as search, selection and deployment, and helps explain why DC will be found not as general dynamic capabilities for change but as particular dynamic capabilities for specific change purposes (Helfat et al. 2007).

DCs are not the only way for an organisation to change. Adaptive change may be routinised as DC, the result of an investment to create and maintain processes for problem-solving, but may also take place on a more ad hoc basis, as a one off response to an external change or crisis (Winter, 2003). Change may also be attributable to luck, accident or talented individuals more than a coordinated organisational response (Teece, 2012). On the other hand, dynamic capability as a latent construct is not identical with its associated routinised responses; there is a difference between 'the organisational and managerial processes, procedures, systems, and structures that undergird each class of capability, and the capability itself' (Teece, 2007: 1321). In terms of the additional content of dynamic capability above the routinised elements, managerial cognition and intent have been proposed (Helfat et al., 2007; Teece, 2012).

There are also theorists, beginning with Eisenhardt and Martin (2000), who argue that while DCs are concrete processes or fixed routines in moderate change environments, they are closer to simple, fragile rules in high change environments (Di Stefano et al., 2014). Recent literature argues that rather than a dichotomy, these alternative forms could instead be viewed as complementary, as even where there is a high level of change these simple rules come bundled with routinized change processes (Peteraf et

al., 2013; Di Stefano et al., 2014; Schilke et al., 2017). We can see this approach in recent empirical work, where dynamic capabilities are identified as higher order routines that support more agile responses to new situations (Heimeriks et al., 2012; Schilke, 2014a).

But search routines, while they may not comprise all that DC involves, are a critically necessary element, and their presence within a firm has the potential to act as a signal for the presence of DC. In so doing, they can also allow us to distinguish between dynamic capability and other, less deliberate, more idiosyncratic sources of change.

Although search routines are accepted in both theoretical and empirical work as a core component of dynamic capabilities, they are rarely used as the basis for operationalizing DC (Di Stefano et al., 2010; Grant and Verona, 2015). For example, Di Stefano et al. (2010) survey and group core papers in the field of dynamic capabilities. Of the 40 papers identified, ten are categorised as both empirically based and focusing on the organisational routines aspects of dynamics capabilities, rather than on individual skills and cognition. None of these ten operationalize the concept of dynamic capability by using search routines.

There have been exceptions, some partial. Zollo and Winter (2002) look at the learning mechanisms that can be used to codify experience into search routines and hence DCs; Schilke (2014a) extends this by examining if these learning mechanisms are themselves routines for codifying experience; and Wohlgemuth and Wenzel (2016) combine measures of change efforts with a single measure of overall routinization to explore the relationship between fluid and routine action; but none of these use search routines to measure DC. Heimeriks et al. (2012) use search routines to study the balance between application of codified operating routines and the need for patterned adaptation and ad-hoc problem-solving. Schilke (2014b) actually uses

search routines to operationalize DCs, and finds that the influence of DCs on competitive advantage can be affected by the level of environmental dynamism. However, no common approach to using search routines, or even to operationalising DCs based on the Helfat et al. (2007) definition has emerged from this small body of empirical work, and it remains the case that the wider field of DC research 'lacks generally accepted approaches to measure its key constructs' (Danneels, 2016: 2175).

We propose to extend and deepen search routines-based empirical research on dynamic capability by linking it more tightly to the theory of DC in key respects. The first is to draw out the implications of Helfat et al. (2007) on DC as organisational capacity to change the resource base in response to shifting external circumstances. If DC entails the use of higher-order routines to re-align operating routines (Winter, 2003), then its strength strictly depends upon and is exhibited in the efficacy of those search routines in relation to the operating routines in need of change. This definitional linkage of DC with its concrete object connects directly with another critical element from the theoretical literature: dynamic capability is specific to a particular class of resource-renewal needs (Nelson and Winter, 1982; Helfat et al., 2007). Modifying, extending, and replacing different kinds of organisational resources and operational capabilities require different kinds of higher-order routines for search and implementation. DC in choosing and integrating corporate acquisitions will generally be of little use in responding to an intensified environmental-regulation regime.

In our case, this means we are looking specifically at dynamic *environmental* capability. Hart (1995) provides an early proposition on how the resources and capabilities required for pollution prevention (contrasted with end-of-pipe pollution control) can reduce not only control costs but also resource waste,

cycle times, legal and regulatory costs, and more. The role of informational search and sharing across companies' internal and external stakeholders in creating environmental capabilities is explored by Wong (2013); Delgado-Ceballos et al. (2012) argue that bringing external stakeholders (including regulators) into the decision neighborhood can advance environmental strategising when managers face internal barriers, and Gabler et al. (2015) investigate the impact on and of such increases in 'environmental orientation.' These insights and others are utilised in constructing and interpreting our empirical research framework, as described in following sections.

Thus we need an empirical methodology that exploits the observability of particular search and operating routines, relevant to environmental impact, *in relation to one another*. The methodology must generate a DC indicator that is sensitive to differing efficacies across firms in identifying and changing those kinds of operating routines.

The research question defined by the foregoing theoretical considerations is: Can we advance the literature by using search routines as the basis for an empirically robust DC indicator that closely links, in observable ways, the routine-changing activities of search with the operating routines that are to be changed? The evolutionary theory of the firm and its precursor in behavioural theory, along with the literature on environmental-management capabilities, offer a rich set of suggestions for the kinds of search activities that might be studied and the criteria by which they ought to be assessed.

## Empirical research framework

Our empirical evidence originates in a multiple case study of adaptation by Irish manufacturers to governmental Integrated Pollution Control (IPC) licensing.

Introduced in 1994, IPC licensing represented a sea change in the environmental regulation of industrial activity. Under the auspices of the Irish Environmental Protection Agency (EPA), the regulations required continuing reduction of environmental impact and a shift of emphasis from end-of-pipe waste treatment to pollution prevention through the adoption of cleaner technology.

Because all firms were required to adopt new manufacturing technology and management practices and to meet new facility-level pollution limits, the setting acts as a natural experiment, potentially throwing into stark relief the role of dynamic capability in responding. Prior work has explicitly identified the potential for dynamic capability to explain adoption and non-adoption of sustainability practices (Eccles et al., 2014). Firms had to learn to do new things and to modify existing practices, in order to continue operating. They needed to locate, process, and act upon information from within and beyond their organisational boundaries in order to reconfigure and extend their relevant capability and resource bases. The speed and efficacy of their responses affected the extent to which the program imposed costs on firms or constrained growth, with the potential in extreme cases to threaten survival.

In line with our research question, we explore the role of dynamic capability in this transition through a multiple case study of routinised search behavior in a sample of IPC-licensed Irish manufacturers. The key elements of the design are: sampling for variation on a key dimension of interest, with controls for comparability; qualitative data-collection using safeguards to reduce participant bias; and triangulating by means of multiple data sources (Eisenhardt, 1989; Langley and Abdallah, 2011). Our goal is qualitative data capable of supporting within-case analysis and then cross-case

comparison, with an eye toward testing, refining and extending the theoretical constructs underlying the study (Gibbert et al., 2008).

### *Sample selection*

In a broader project (Goldstein et al., 2011), we explored IPC-driven technological and managerial practices and pollution-level outcomes among 59 firms in three Irish industry sectors: metal fabricating, paint and ink manufacturing, and wood sawmilling and preservation. We chose these sectors for three reasons. First, for generalisability, we sought sectors exhibiting a range of technology, product and market characteristics. Second, we favoured industries with a high percentage of single-facility firms, where facility-level environmental data would match with firm-level financial data. And finally, we avoided sectors subject to substantial transfer-pricing bias due to facility 'sales' to same-firm subsidiaries elsewhere.

This study is based on in-depth case interviews conducted with managers at a subset comprising 13 firms. We eliminated sawmilling from this group in the interest of comparing like to like; wood-products firms employ a narrower range of simpler technologies, and often consist of only an owner and a small staff. Although the metals and paints firms are small to medium-sized organisations, they exhibit structured organisation, and it is in that context that we wanted to study DC. Five case firms from the paint and ink sector and eight from metal fabricating were chosen for variation in environmental performance (Eisenhardt, 1989; Stake, 1994).

### *Environmental performance measures*

There is a large environmental-management literature on the dimensions and determinants of companies' impacts. We drew heavily upon this research in targeting

and designing sector-appropriate but cross-sectorally comparable measures of environmental impact (for example, MEPI, 2001; Karavanas et al., 2009) and the corporate practices that affect them (for example, Dewulf and Van Langenhove, 2005; Fijal, 2007). Details can be accessed in Goldstein et al. (2011). The resulting variables, described below, provide some of the fine-grained inputs required to implement our theoretically-grounded strategy of observing the action of search upon the operating routines and resource base to be changed.

*Data Sources*. IPC licenses specified permissible limit values and monitoring protocols for each emission of concern at licenced facilities. EPA required firms to develop rolling five-year environmental-management programmes of continuous-improvement plans and projects intended to realise those plans. Each firm had to submit an annual environmental report (AER), detailing all environmental–monitoring results mandated in the license, as well as projects under way that year, with measurable goals, target dates and progress made. The EPA audited firms, producing audit reports, including facility inspections, reports on conditions observed, results of tests performed, and observations regarding environmental-management projects and practices. Finally, EPA sent notices of noncompliance with terms of the license, which provided data on noncompliance and the potential for punitive administrative or legal action.

These documents provided information about the specific regulatory requirements under which each firm operated and their efforts to satisfy those requirements. Based on that information and the extensive literatures on environmental impact-reduction generally and in each industry sector, we created measures of environmental management practices, technology adoption, and impacts such as emissions. The

result was a panel of data on the 59 firms from 1996-2004. Following are summaries of the indicators to be used in the present study; full details can be found in Goldstein et al. (2011).

*Environmental impacts: emissions and waste*. Key emissions specified in the IPC licenses were combined in a firm-level index, with controls for differences in production scale and cross-sector comparability. Reported waste tonnages were similarly processed for within and across-sector comparability. For this study, each firm's all-years average emissions and waste values were converted into a percentile rank for each firm among all 34 firms in the broader study's metals and paints sectors: '$100^{th}$' represents lowest emissions or waste.

*Technology adoption*. Cross-sector comparability was achieved by locating all environmental technology projects for each facility in each year in a common matrix, based on stage in the production process by pollution-reduction approach. Projects were scored according to sector-specific technical sources, based on scope within the firm and degree of clean-technology sophistication. This was converted into a percentile rank for each firm among all 34 firms in the broader study's metals and paints sectors: '$100^{th}$' represents highest clean-technology adoption.

*Regulatory compliance*. EPA non-compliance notices were scored according to severity based on the consistent language used by the agency. This indicator addresses performance in that it reflects the firms's success in meeting its license requirements. With IPC licensing, the regulatory relationship becomes a condition of doing business: it affects cost and even, in extreme cases, survival. Thus, it is a matter of evolutionary 'fitness' in the sense proposed by Helfat et al. (2007: 7). The 'positive,' 'negative,' or 'adversarial' values for the regulatory-relations performance variable

were assigned based on number of non-compliances, severity, and a qualitative assessment by the researchers.

### *Case study data on search routines and dynamic capability*

*Case interview protocol.* We contacted the manager identified from EPA records as responsible for environmental matters. Of ten paint firms contacted, five accepted, and eight of fifteen metal-working firms agreed to be interviewed. The data on the environmental-performance variables discussed above indicates that the firms entering the case study represented a range of performance outcomes very similar to those that declined.

Two researchers conducted each interview on-site, except in an instance when one was ill, with the conversations lasting in the range of an hour. We interviewed environmental managers about organisational processes and dynamics. The interviews were approached using the critical incident technique (Butterfield et al., 2005). By anchoring the interview around specific environmental projects - both successful and unsuccessful - which we had identified from the EPA records, we were able to keep the interview focussed without directing or circumscribing the information provided by the informant (Chell, 2003). After the manager told the story of a key project, we then probed the processes underlying its identification and implementation, with particular attention to evidence of routinised search. By connecting discussion of processes to a concrete event, managers' recall was sharpened and accounts were more likely to be linked to evidence.

Interviews were recorded, with notes taken during the interviews and site visit, and review of the recordings very soon afterward. Preliminary write-ups then ensured that

researcher impressions were captured while fresh. Recordings were transcribed. We used the transcripts, memos and case notes for the creation of qualitative data.

*Case data construction: Search routines.* We coded for routinised search in the following steps, detailed below: 1) defining observable search-activity categories; 2) supplementing case-interview records via triangulation with information from EPA archives; and 3) application of search-activity scoring criteria from the literature. Following the search-routines data construction, we assessed the ensemble of scored SRs to create a measure of DC.

1. The first step was to specify the categorical content of the search routines. Following Simon (1955) and Cyert and March (1963), Nelson and Winter (1982) argue that to change organisational routines at the operating level, search routines must enable the firm both to identify and to implement new or modified alternatives. What specific kinds of observable activities would be involved in locating, evaluating, and acting upon the information these firms needed, potentially from within and outside the boundaries of the organisation? We emphasise the role of context-specificity (Helfat et al. 2007); for example, cleaner-technology adoption requires management of specific information and skills in analysing alternatives, measuring results, and coordinating environmental strategy (Christie, 1995). In an iterative process between the literature and the data, we identified the following categories of processes aimed at search activity. Each of these categories is intended to provide inputs for assessing the environmental management-specific interface between change processes and the very concrete operating routines and resources upon which those processes work:

1a. Planning. This relates not to 'planning' *qua* orderly execution of pre-determined activities, but rather to processes for the purposeful organisation and processing of the search for information while evaluating possible courses of action. An example is a regular planning group that meets to scan for future needs, set environmental priorities and commission specific search projects.

1b. Use of data. On-going reductions in emissions and waste require processes for gathering and analysing data on the nature and causes of facility pollutant streams and testing the potential of options for limiting those streams: determining the necessary data and how best to collect it, implementing this, and incorporating data into decision-making.

1c. Team problem-solving. Team work processes enhance search by extending the range of skills and knowledge brought to bear, helping generate and vet ideas for where to look and how, and strengthening processing capacity. Environmental impact-reduction problems intrinsically cut across functions like manufacturing, product and process design, purchasing, and R&D; thus, cross-functionality can be a valuable dimension of team-based search.

1d. Multiple information sources. More and better sources of information broaden the field and deepen the quality of search. We looked for organisational processes for seeking and engaging with external sources for the purposes of learning, such as peer firms, consultants, suppliers, professional associations, certification processes (e.g., ISO 14001 and EMAS), university research bodies, industry programs, and the EPA itself.

1e. Integration of external expertise. Relationships with outside experts can be pursued in ways that either strengthen or outsource the firm's search capacity. Processes to ensure that use of external expertise is collaborative and internally integrated contribute to this capacity.

2. We were able to supplement information on these search-activity categories by triangulating with EPA data. Firms' environmental management programmes and annual AER reports were used where possible to confirm our reading of case records or stimulate us to take another look.

3. The final step in processing observed search activity was to establish clear criteria by which each categorised set of activities would be ranked for routinisation. Becker and Zirpoli (2008) propose a set of criteria for understanding how organisations use routines to accomplish key tasks. Borrowing from them, we scored the level of each search category for each firm as high, medium, or low according to:

3a. Recurrence - frequency increases routinisation.

3b. Collectivity - when activities are organisational and not merely individual, they become more patterned and more institutionalised, whether formally or not.

3c. Degree of interdependencies-coordination. Becker and Zirpoli argue that the 'literature considers interdependence as the key problem that organization addresses…' and that to be meaningful, routines should 'play a role in… providing coordination of how interdependent tasks are accomplished' (132).

*Case data construction: Dynamic capability*. We completed case data-construction by moving to a DC scoring. A search routine is not a higher-order capability. But an

ensemble of search routines, functioning purposefully over time to locate, sift, evaluate, choose, and initiate implementation of new operating routines, can constitute a higher-order capability. Setting out clear criteria for assessing that functioning is the final step in empirically connecting search to its theorised object: taking the inputs provided by the five search categories described above, as scored individually for routinisation strength, and assessing what is required for search to engage with and change the relevant operating routines. As a principle for assessing the case firms' search routines for their dynamic-capability implications, we used Helfat and Peteraf's concept of 'embeddedness': 'exercised regularly, the capability becomes more deeply embedded in the memory structure of the organization' (2003: 1003). There are three ways in which observed sets of search routines could work together to exhibit varying levels of embeddedness:

1. *Durability*. Are the routines persistent over time? This may differ from 'recurrence' as used above; it suggests activity that survives a significant time period.
2. *Generalisability across a range of environmental impacts*. Highly embedded SRs are not limited to specific problem areas, but are practised enough to be applied across different instances of this class of resource-base changes as identified in the environmental-management literature.
3. *Integration into broader management processes*. Even very substantial environmental-management search activity, if detached or siloed apart from core management decision-making – strategy, capital budgeting, product development, personnel – may not translate into the capacity to reconfigure or extend organisational resources and operating routines. As noted by behavioral theorists (Cyert and March, 1963), effective search

must place participants in the managerial decision neighbourhood, and – related – be congruent with salient coalition members' goals.

Search routines with higher levels of these characteristics are more deeply embedded parts of the firm's overall repertoire of organisational routines and would be expected to support, and thus indicate, stronger DC. This is applied as a holistic assessment of the suite of routinised search processes, analysed empirically in terms of the theorised linkage of search routines with the concrete operating routines and resource base they are intended to affect.

### *Validity and Reliability*

Well-known shortcomings of case studies (Miles and Huberman, 1994) can be mitigated with care to ensure validity – empirically representing the key characteristics and relationships identified in the theoretical concept – and reliability – avoidance of excessive researcher subjectivity that could endanger replicability across researchers and settings.

We use a set of validity definitions from Gibbert et al. (2008). Construct validity refers to 'the quality of the conceptualization or operationalization of the concept' (1466). Our empirical SR categories and DC measure were defined and constructed in careful relation to definitions in the literature. We employed a broad view of 'search,' consistent with Nelson and Winter (1982) and Teece (2007) among others; our definition of 'DC' follows Helfat et al. (2007: 4) by focusing on a firm's 'capacity… to purposefully create, extend, or modify its resource base.' We think it reasonable to argue that the search activities as observed, categorised and scored, and used in combination as assessed, would contribute to that capacity.

Internal validity requires logically persuasive reasoning in applying the constructs during data analysis (Gibbert et al.: 1466). During cross-case analysis as reported in the next section, we carefully allowed for the possibility of alternative sources of environmental performance other than DC. We also noted the consistency between our findings as analysed and those expected from a reading of the literature.

Finally, external validity refers to the analytical generalisability of the method and conclusions to other settings (Gibbert et al., 2008: 1468). We have sought to ensure this by means of careful and transparent sample selection at the start and cross-case analysis at the end of the case protocol (Langley and Abdallah, 2011).

Issues of generalisability and transparency are related to the need also for reliability: a minimum of subjective inference by the researcher, to enhance replicability across researchers and/or different data applications with consistent results (Gibbert et al., 2008; Seale, 1999). Our study supports replicability by adhering to an accepted protocol (Eisenhardt, 1989; Langley and Abdallah, 2011). The protocol includes clear and simple principles for case selection, data construction, and analysis. Researcher subjectivity at the critical case-information collection stage is reduced by means of multiple interviewers, audio recording, and rapid write-ups. Replicability is especially important in this instance, because the essence of the research question is whether the proposed method provides an applicable operationalisation of a well-known theoretical proposition.

## Findings

We begin at the level of each individual case, illustrating with three of those analysed: one each determined to exhibit high (Metal1), medium (Metal3) and low (Paint3) DC.

We then analyse the patterns and implications arising from comparison across all 13 cases. (See Eisenhardt, 1989 and Langley and Abdallah, 2011 on this sequencing.)

### *Search routines and dynamic capability in the case firms*

In discussing these findings for our three exemplar cases, we pay special attention to their search-routines scoring using the Becker and Zirpoli (2008) criteria for individual search categories. We then continue on to the DC implications by focusing on embeddedness criteria (Helfat and Peteraf, 2003) for the ensemble of search routines. The Appendix tables present detailed outlines for the full set of cases.

Based on that detail, Table 1 reports by firm the scores assigned for each of the search categories – planning, use of data, team problem-solving, external information sources, and use of outside expertise – using as criteria recurrence, collectivity, and interdependencies-coordination.

Table 1 about here

*Metal1*'s search activities emerged in response to a prolonged compliance crisis; this uncertainty sparked commitment to environmental-management search, which grew cumulatively over time with increased confidence in the efficacy of the relevant managerial actions (Aragón-Correa and Sharma, 2003). Search-related evaluative planning activity was intense and continual, thus highly recurrent. Relevant data was identified, gathered and analysed in looking at alternative technological solutions. Team problem-solving was featured prominently: in a cross-functional group that explored a wide range of possible technical solutions, and in goal-setting and coordination through monthly meetings of the environmental team. Thus search was highly collective, and coordinated interdependencies among the manufacturing,

environmental, capital budgeting, and other functions. A wide variety of outside information sources included technical exchange with a US firm, vendor initiatives, and consultants. Yet all of these sources were managed for internal capacity-building, both enhancing and supported by the collectivity of the search processes (Wong, 2013). Thus all five search-activity categories were amply observed and search routines were rated as 'high' across the board.

*Metal3* also struggled initially to comply with its licence. A cross-functional environmental management team exhibited planning with a good deal of recurrence and collectivity but little evidence of routine setting of goals and priorities ('medium' for both planning and team problem-solving). There was also little evidence of data usage in planning ('low'). Related, although a wide range of outside information was accessed ('high') – consultants, ISO 14001, vendors, peer firms, etc. – projects tended to rely on outsiders for the evaluation of technical solutions and led to purchases of complete solutions rather than adding internal capability ('medium'). This dynamic also limited interdependency-coordination (Wong, 2013); for example, where possible Metal3 aligned environmental improvement with general equipment upgrading but left identification and exploitation of these opportunities to consultants and vendors.

*Paint2* is small firm but had a full-time environmental manager due to severe and contentious environmental issues inherited on a new plant site. The EM conducted a lot of evaluative planning, recurrently but on his own rather than collectively (planning was scored 'medium' and team problem-solving 'low'). There was no evidence of systematic data use in environmental search ('low'). The firm was creative about using the EM with both customers and suppliers to make changes to

the way raw materials and products were packaged, turning these relationships into outside information sources ('medium') that sometimes added to in-house expertise ('medium').

We conclude the within-case analysis by showing how we translated this observable search activity into a dynamic capability measure. Here we apply the criteria inspired by Helfat and Peteraf's (2003) 'embeddedness' concept: to what extent did each firm's ensemble of search routines function together to be durable, generalisable, and integrated with overall management? Table 2 provides summaries for all case firms, now grouped by assigned DC level.

Table 2 about here

*Metal1*'s search routines were developed and refined over a period of many years (highly durable). The range of technical issues addressed, means of addressing them, and sources of expertise suggested wide applicability (easily generalisable across the pollution-prevention space as in Hart, 1995). The firm was pushed by EPA-initiated legal actions to incorporate environmental search at all management levels (well integrated with overall management processes). In effect, management accorded the regulator legitimacy as a coalition member whose own goals became highly salient to the firm (Cyert and March, 1963; Delgado-Ceballos et al., 2012). Its suite of search routines illustrates the firm's strong capacity for modifying and adding to its repertoire of operating routines in adapting to marked change in the environmental-management demands imposed by its external circumstances: we assessed its DC as 'high.'

*Metal3's* search processes extended over many years and were well institutionalised (quite durable), though delimited due to outsourcing. Search capacity developed over

both production-process and waste-disposal projects, with the firm's reliance on outside expertise and turn-key solutions both a strength and a weakness (moderately generalisable). The environmental manager worked closely with their senior report, and they coordinated environmental improvement with general equipment upgrading (integrated with management, as in Augier and Teece (2008), via a reporting line). The overall picture from viewing its search routines *in toto* is a firm with moderate but not exceptional DC with respect to its environmental-management resource base.

*Paint2* was assessed as 'low' DC in relation to the overall capacity revealed by the search routines in combination. Because its recently hired environmental manager was the sole locus of relevant problem solving and supplier and customer relationships, the related search was likely vulnerable to the tenure of that key employee (low durability). In addition, despite a moderate number of search activities, there was little evidence that they would have an extended range of applicability beyond market relationship-building – for example, pollution-preventing process changes as in Hart (1995) (low generalisability). Finally, environmental search was limited to the EM function and solely his responsibility (poorly integrated with the 'decision neighborhood' of overall management, as in Augier and Teece (2008)). Thus, in indicating DC, the firm's individual search routines added up to less than the sum of the parts.

### *Dynamic Capability and Performance*

Ultimately, ascribing differential levels of DC to a group of firms should help us understand how effective they are in accomplishing key tasks required for survival and profitability – that is, something about their relative performance. The regulatory relationship was often a function of key managers' or owners' attitudes toward the

EPA (Raaijmakers et al., 2015). But these firms' ability to meet the heightened regulatory demands of IPC licensing constituted a newly-important kind of competitive performance. Differential fitness levels in this sense (Helfat et al., 2007) could have impacts ranging from equipment costs to legal expenses to managerial time and focus – even to the ability to continue to operate. Thus, if they were to protect or advance their viability, these firms did not have the luxury of ignoring or delaying the changes being required of them (Raaijmakers et al., 2015). Given that achieving fitness in the sense just defined required at least forebearance on the part of the regulatory 'coalition' aspirant (Cyert and March, 1963), there was little choice.

Does the cross-firm DC measure derived from observed search activity help in understanding case firms' differential performance in this sense, and how does that relate to theoretical expectations passed on from the literature? Table 3 groups the case firms by assigned DC level, from 'high' in the top panel to 'low' at the bottom. It also shows each firm's environmental performance measures: The pollution and clean-technology percentiles given in Table 3 show each firm's rank among all 34 firms in the broader study's metals and paints sectors; the percentiles are defined so that '$100^{th}$' represents best in class, that is, lowest pollution or highest clean-technology adoption. The 'positive,' 'negative,' or 'adversarial' values for the regulatory-relations performance variable are assigned based on number of non-compliances, their severity, and a qualitative assessment by the researchers.

Table 3 about here

The data in Table 3 suggest an association between DC level, as measured, and environmental performance: higher-DC firms tend to have relatively less pollution, more clean technology, and less onerous relations with the EPA. We pursue this

through Table 4, which examines the patterns by showing individual firms' environmental performance quartiles, again demonstrating that DC is associated with higher environmental performance; and Table 5, which aggregates further to show each DC-level group's average standing across all three environmental-performance levels, with the level of DC reflected in the level of environmental performance.

Tables 4 and 5 about here

## Discussion

Our research question asks whether we can advance the literature by using search routines as the basis for an empirically robust DC indicator that closely links, in observable ways, the routine-changing activities of search with the operating routines that are to be changed. We identify DC conceptually as 'latent action' (Di Stefano et al., 2014), then observe and measure it from routinised search processes working in combination to modify and extend the firm's environmental-management resource base. Our research demonstrates the approach and extends the literature on this point.

The search process categories we define are observable in the interview records and corroborated in the firm's EPA files. Although firms' relevant activities are idiosyncratic in detail, we are able to identify many that are used commonly to drive change. Our approach involves a minimum of subjective inference by researchers to locate and sort the observed activities. Assessing these search activities by application of the Becker and Zirpoli criteria (2008) is straightforward. Once assembled, these search-routine rankings allow us to proceed directly to an ordinal measure of the strength of a firm's DC. Embeddedness (Helfat and Peteraf, 2003) guided creation of ranking criteria that produced assignments into DC categories.

To make them tractable to our empirical method, we broke down search routines to a fine-grained level. Table 1 shows the range of variation in these categories: a little within-firm and a lot across firms. In terms of understanding DC, the key is not individual search activities, but how they interact with one another and other organisational processes. Heavy use of consultants might or might not compromise the contribution of outside information-sourcing to the firm's own DC; it depends on how that outside expertise is used (Metal1 vs Paint3). Frequent collection of data on environmental impacts can enhance DC if it is fed into evaluative planning and problem-solving (Paint1), but not if it is merely aimed at demonstrating compliance (Paint5). Assessing SR scores based on embeddedness in creating a DC measure allows us to attend empirically to interactive integration in comparing the implications of observed search activities across these firms. This holistic approach is the implication of defining and exploring dynamic capability in terms of the processes by which operating resources and capabilities are changed. It allows us to bring to bear quite precisely a broad range of theoretical predictions and empirical findings from the DC and – given the content-specificity of DC (Winter, 2003) – environmental-management research literatures.

At increasingly summary levels of aggregation, Tables 4 and 5 suggest a strong association between DC and these firms' environmental performance relative to one another. But, as expected, there is quite a bit of variation, as other factors are likely to be in play. DC and performance are not expected to march in lock-step. DC might be exercised to develop new operating capabilities that are not the ones demanded by the changed competitive setting (Helfat et al., 2007). And other factors might also affect IPC-licencing performance – for example, product and process mix, physical setting, and other firm-specific factors not related to DC *per se*. With a conceptual and

empirical definition of DC that is robust, in its linkage of observable search activities with the class of operating routines needing to be changed, we should expect to find these kinds of variations (Arend and Bromiley, 2009).

The case summaries are illuminating about this variation in the DC-performance relationship and demonstrate the insight that a fine-grained measure of DC can support. For example, Metal1's high level of DC helped the firm recover from a "disastrous" combination of a very polluting production process and an environmentally sensitive location to rather middling performance levels. Metals6 and 7 in the 'medium' DC category are firms whose progress in building DC helped them begin to address still-serious environmental problems inherited from the past. In the 'low' DC group, Metal2, by the lucky happenstance of a benign production process, had reasonably good emissions performance and little need to invest in either cleaner technology or building DC; while Paint2 achieved mostly-good performance levels by virtue of a highly effective environmental manager working strictly on his own, but creating few durable, generalisable, integrated search processes.

Our method was efficient in its application, but was it effective in capturing and elucidating dynamic capability? DC means capacity to reconfigure and extend the firm's resource base in line with changing circumstances. Is that what we saw? The outcomes of the search routines employed by the higher-DC among these firms were new assets and capabilities in environmental impact-reduction. These included cleaner technologies, long-term market relationships with suppliers and customers, and lasting organisational systems and knowledge. This resource-base renewal underlay our findings as reported above.

We would argue that the cross-case analysis suggests that our research question is answered in the affirmative: a DC indicator based on observed search routines, analysed in relation to the operating resources and routines at which they are aimed, can help us understand performance differences among firms as they adapt to change. The overall pattern in the case data suggests that observed 'exceptions prove the rule': DC generally allows firms to perform better at changing to meet the demands of a changing competitive environment (Di Stefano et al., 2014: 312). Focusing empirically on the space where DC must engage with existing operating routines and resources, we are able to distinguish between cases in which it drives change and boosts performance; those where it drives change but cannot move the performance needle much; and those in which good performance is achieved in its absence. In general in these results, DC strengthens evolutionary fitness, but the relationship is complex as it is expected to be.

### *Reliability and validity in empirical dynamic capability research*

To have advanced DC research meaningfully, our demonstration of how to extend and apply the theoretical injunction to focus on the search routines-operating routines interface must have been achieved *validly* –capturing the key characteristics identified in the DC concept – and *reliably* – requiring a minimum of subjective inference by the researcher, to enhance replicability. We have already discussed the steps taken to ensure reliability and validity of our research. We turn here to how adoption of our DC measurement approach could support validity and reliability in future research.

*Validity* in an indicator is provided when it captures the theoretical concept being measured (Silverman, 2011). Only if it inspires confidence that what we say we are measuring is actually what we are measuring can the claims to knowledge made on

the basis of that indicator have credibility. Many theoretical developments of the dynamic capability concept have emphasised search routines as its centre (Zollo and Winter, 2002; Winter, 2003; Becker *et al*., 2005; Teece, 2007; Helfat et al., 2007). What we have contributed is to show that search routines can provide for discriminant validity (Grant and Verona, 2015) by identifying the specific content and role of the DC. When analysed in close context with their concrete object, these routinised search processes can be distinguished from *ad hoc* problem solving or from solo efforts relying on the skills of one key staff member. By identifying specific processes by which the work of learning and change gets done, this search routines-based methodology provides researchers with a theory-based means to get at something we can validly claim as DC, testing for example its organisational origins and concomitants and its specificity and range of generalisability, in different settings.

*Reliability* suggests that the deployment of an indicator is replicable across researchers, and/or different data applications, with consistent results. This is provided here by offering specific guidance for what kinds of search activities are relevant and via descriptive concreteness of the basic characteristics of search routines – recurrence, collectivity, coordination – and of ensembles of search routines considered as DC – durability, applicability range, managerial integration. In translating from the underlying data to the calculation of the indicator value, there is a minimum of subjective interpretation by either respondents who are reporting actions or researchers who are processing those reports (Seale, 1999). This mitigates the well-known problems associated with relying on the perceptions and recall of managers (Grant and Verona, 2015) and increases replicability of the measure.

### *Implications for Further Research*

We focus here on three potential extensions of this approach. One would be adaptations of our search and DC measure-construction steps to other settings. This process will identify problems with the approach, test the limits of its applicability, and (if warranted) refine it and make it a still-more robust and adaptable empirical tool of DC research.

We also see the method being developed through being applied where different kinds of performance are at stake. In the present research context performance had to do with evolutionary fitness with respect to a critical environmental-regulation regime change. But learning, adaptation and resource renewal clearly can affect any significant kind of performance. This could lead to different applications where, like in ours, the performance dimension with related DC is rather specialised and can be studied by close attention to the linkage between specific search activities and the class of operating routines to be modified or replaced. The method could also, and clearly should, be tested in terms of the fundamental kinds of performance represented by sustainable competitive advantage and the generation of rents.

Finally, a measure based on fine-grained activities allows for closer examination of how those activities interact and are integrated with their organisational setting. A long literature suggests that DC entails learning and knowledge creation (Argote and Miron-Spektor, 2011; Becker, 2005; Kogut and Zander, 1992; Winter, 2000), and that knowledge creation requires effective integration across the organisation's functions and individuals (Grant, 1996). Future research using our proposed approach could address the significant question of the role of knowledge and learning in dynamic capability development (Argote, 2011).

## Conclusion

Dynamic capability cannot be seen; it is a latent construct (Hult et al., 2002) regarding latent action (Di Stefano et al., 2014). Its appeal as a concept lies in solid theoretical grounding in a compelling story about organisational processes for identifying, assessing, and implementing new ways of doing things. Helfat et al. (2007: 37) solved the unobservability problem theoretically by suggesting that the latent capacity represented by DC might be empirically investigated from a process perspective. Our contribution is to extend that theoretical solution in a direction that enables such empirical investigation: to observe and measure DC based on routinised search processes at work in attempting to change the firm's resource base. We elaborate a replicable methodology based on that approach.

Defining dynamic capability as patterned and intentional routine-changing search draws a distinction with other kinds of factors that may lead to improved performance, such as luck, *ad hoc* problem solving, or spontaneous reactions (Ambrosini and Bowman, 2009). This means that we need a way to operationalize dynamic capabilities that can identify clearly where deliberate processes are at work in modifying the firm's resource base and distinguish these from other drivers. The methodology described here allows us to do that. Qualitative data generated from case interviews was analysed alongside corresponding quantitative data on technological and managerial practices and performance outcomes.

DCs are theorised to involve at least partly tacit knowledge which by definition may be hard to identify in the data record. In following the literature's suggestion to pursue a search process-based empirical approach to DC (Helfat et al., 2007), we confronted the fact that these complex process-based phenomena are often not codified to the

point where they are amenable to quantitative instruments (Langley, 2007). We have thus worked also with qualitative, context–rich information that is both concrete and rich (Graebner et al., 2012).

With the advent of IPC licensing, specific kinds of environmental performance became relatively more important among the myriad potential determinants of profitability for Irish manufacturers. Competitiveness relative to industry peers could now be affected by the direct and indirect costs and benefits of IPC regulation. Firms' differential DC – in their speed, vigour, and efficacy in the relevant kinds of adaptation and change – affected their evolutionary fitness in mediating this competitive impact. What was required was highly content-specific in terms of the duo of capability for change and capabilities to be changed (Winter, 2003); firms' environmental-management resource base had to be developed through dynamic *environmental* capability. Thus in its particulars, we have proposed a methodology for specifying, measuring, and testing the role of DC in that application field. But with similar attention to content-specificity in search and its objects, this approach should be easily adaptable to studying DC aimed at renewing organisational resource bases with respect other kinds of significant adaptation problems.

There are limitations to using search routines to underpin an indicator of DC. It requires fine-grained information about organisational activity that can be difficult and time-consuming to obtain; meeting this requirement is likely to be especially challenging outside settings where a regulatory or industry body has provided a start by gathering useful data across firms (Eccles et al., 2014). In addition, to the extent that tacit and/or informal elements are critical in a given setting, our DC indicator – because it relies on observable, routinised change processes – might need to be supplemented with approaches tailored to identifying those elements.

Search routines at work are a necessary, if not always sufficient, component of dynamic capability and provide an empirical opportunity to get at the phenomenon rigorously. Despite its fundamental unobservability, dynamic capability can be observationally represented and its complex relation to organisational change and performance examined empirically.

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**Table 1 Routinised search activities**

*Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination.*

| Case | Planning | Use of Data | Team Problem-Solving | External Information Sources | Integration of Outside Expertise |
|---|---|---|---|---|---|
| Paint1 | High | High | High | High | High |
| Paint2 | Medium | Low | Low | Medium | Medium |
| Paint3 | Low | Low | Low | Medium | Low |
| Paint4 | Medium | Medium | Low | Low | Low |
| Paint5 | Medium | Low | Low | Low | Medium |
| Metal1 | High | High | High | High | High |
| Metal2 | Low | Low | Low | Low | Low |
| Metal3 | Medium | Low | Medium | High | Medium |
| Metal4 | Low | Low | Low | Low | Low |
| Metal5 | High | Medium | High | Medium | Low |
| Metal6 | Medium | Medium | Medium | Medium | High |
| Metal7 | Medium | High | Medium | Medium | High |
| Metal8 | Medium | Low | Medium | High | Medium |

Notes:
Scoring details are in Appendix tables.
Scoring criteria are from Becker and Zirpoli (2008).

**Table 2 Dynamic-Capability assessment from search routines**

*Each suite of scored environmental search routines assessed by 'embeddedness': 1) durability, 2) generalisability, and 3) integration with overall management*

| Case | SRs Average | 'Embeddedness' Assessment | **Dynamic Capability** |
|---|---|---|---|
| Paint1 | High | 1) Extending over many years from licensing.<br>2) Spanning a wide range of environmental issues.<br>3) Integrated with core management (e.g., capital-budgeting), which incorporates & facilitates environmental-management search. | **High** |
| Metal1 | High | 1) Search routines developed and refined over a period of many years.<br>2) Range of technical issues addressed, means of addressing them, and sources of expertise suggests wide applicability.<br>3) Pushed by EPA to incorporate environmental search at all management levels. | **High** |
| Metal5 | Medium | ***Strong embeddedness suggests boosting SR-average:***<br>1) Developed over many years and very institutionalised.<br>2) Widely applicable – search capability deployed across a range of problem and solution types.<br>3) Central to strategic management during repeated spans. | **High** |
| Metal3 | Medium | 1) Extend over years and well institutionalised, but limited by outsourcing.<br>2) Developed across production-process and waste-disposal projects; focus on outside expertise and turn-key solutions both helps and hurts.<br>3) Environmental manager works closely with senior report; search coordinated with general equipment upgrading. | **Medium** |
| Metal6 | Medium | 1) Capacity built over time through recurrent activity, but appears very much dependent on the energy and creativity of one employee.<br>2) Applicable to range of compliance issues, not forward-looking change.<br>3) Compliance focus and one-person basis limit strategic integration. | **Medium** |
| Metal7 | Medium | 1) Number & frequency of environmental search activities growing but still limited. Institutionalisation still emerging from the *ad hoc*.<br>2) The approach to environmental search makes it broadly applicable.<br>3) Relevant SRs not yet embedded deeply in core organisational processes. | **Medium** |
| Metal8 | Medium | 1) Frequent & fairly institutionalised, but vulnerable to culture issues.<br>2) Broadly applicable across internal and external search.<br>3) Aim to work environmental & general efficiency search in same direction helps integrate yet can put the former at the back of the line. | **Medium** |

Notes:
Search-routine and dynamic-capability scoring details are in Appendix tables.
'SRs Average' calculated by assigning Table 1's category ranks 3 for 'high,' 2 for 'medium,' 1 for 'low.'
'Embeddedness' concept is from Helfat and Peteraf (2003); assessment criteria developed by the authors.

**Table 2 continued on next page.**

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**Table 2 (Continued) Dynamic-Capability assessment from search routines**
*Each suite of scored environmental search routines assessed by 'embeddedness': 1) durability, 2) generalisability, and 3) integration with overall management*

| Case | SRs Average | 'Embeddedness' Assessment | **Dynamic Capability** |
|---|---|---|---|
| Paint2 | Medium | ***Weak embeddedness suggests reducing SR-average:***<br>1) Likely vulnerable to tenure of environmental manager.<br>2) Little evidence of extended range of applicability of SRs.<br>3) Limited to the environmental-management function and solely his responsibility. | **Low** |
| Paint3 | Low | 1) Neither recurrent nor institutionalised.<br>2) Little internal search capacity that could be generalised.<br>3) Any environmental search that occurs is isolated in the environmental-management individual and function. | **Low** |
| Paint4 | Low | 1) Little institutionalisation, although environmental search has increased over time.<br>2) Search focus has been on narrow range of cost-related waste problems.<br>3) Senior management is involved only in signing off on EM's decisions. | **Low** |
| Paint5 | Low | 1) There is recurrent activity that is based in ownership/top management.<br>2) Limited to after-the-fact monitoring and testing, not extended to learning and change in processes or products.<br>3) Exercised by ownership/top management, but search activities appear wholly separate from strategic, operational considerations. | **Low** |
| Metal2 | Low | 1) Little sign of recurrent, institutionalised environmental search.<br>2) Insufficient routinised, project-focused activity to support wide applicability of search capacity.<br>3) Almost wholly detached, in the person of the quality/environment manager. | **Low** |
| Metal4 | Low | 1) Any search capacity is intermittent and fragile.<br>2) Insufficient activity to create a widely-applicable search capability.<br>3) Intermittent and isolated from overall operating or strategic functions. | **Low** |

Notes:
Search-routine and dynamic-capability scoring details are in Appendix tables.
'SRs Average' calculated by assigning Table 1's category ranks 3 for 'high,' 2 for 'medium,' 1 for 'low.'
'Embeddedness' concept is from Helfat and Peteraf (2003); assessment criteria developed by the authors.

**Table 3: Environmental performance in DC groups**
(by percentiles or, last column, summary measures)

| Case | Emissions/Waste[a] | Clean Technology Adoption [a] | Regulatory Relations[b] |
|---|---|---|---|
| P1 | Emissions: 97th<br>Waste: 19th | 100th Percentile | Pollution non-compliances: zero<br>Relationship with EPA: positive |
| M1 | Emissions: 50th<br>Waste: 74th | 73rd | Pollution non-compliances: high<br>Prosecuted unsuccessfully by EPA<br>Relationship with EPA: positive |
| M5 | Emissions: 100th<br>Waste: 52nd | 55th | Pollution non-compliances: low<br>Relationship with EPA: neutral |
| M3 | Emissions: 0th<br>Waste: 4th | 58th | Pollution non-compliances: high in past but now compliant.<br>Prosecution threatened by EPA<br>Relationship with EPA: now positive |
| M6 | Emissions: 7th<br>Waste: 70th | 9th | Pollution non-compliances: high<br>Prosecutions by EPA<br>Relationship with EPA: now positive |
| M7 | Emissions: 22nd<br>Waste: 37th | 42nd | Pollution non-compliances: high<br>Prosecution threatened by EPA<br>Relationship with EPA: now positive |
| M8 | Emissions: 89th<br>Waste: 30th | 97th | Pollution non-compliances: zero<br>Relationship with EPA: positive |
| P4 | Emissions: 61st<br>Waste: 11th | 36th | Pollution non-compliances: zero<br>Prosecutions by EPA;<br>Relationship with EPA: neutral |
| P2 | Emissions: 18th<br>Waste: 59th | 79th | Pollution non-compliances: zero<br>Relationship with EPA: neutral |
| P3 | Emissions: NA<br>Waste: 67th | 27th | Pollution non-compliances: zero<br>Prosecution threatened by EPA<br>Relationship with EPA: negative |
| M2 | Emissions: NA<br>Waste: 85th | 6th | Pollution non-compliances: high<br>Relationship with EPA: negative |
| P5 | Emissions: 29th<br>Waste: NA | 67th | Pollution non-compliances: zero<br>Relationship with EPA: negative |
| M4 | Emissions: 11th<br>Waste: NA | 21st | Pollution non-compliances: high<br>Relationship with EPA: negative |

a: **Percentile** within full two-sector sample (34 firms: 21Metals and 13 Paints). **100th = 'best'** (lowest emissions/waste, highest clean technology adoption).
b: **Positive** = the firm describes the regulator as a source of advice and support; **neutral** = the firm neither has regulatory problems nor expresses a positive perception of the regulatory relationship; **negative** = the firm has a significant burden of effort in dealing with prosecution and/or regulatory attention.

| **Table 4: Dynamic capability and environmental performance in DC groups** | | | | |
|---|---|---|---|---|
| Case | Dynamic Capability | Emissions/Waste[a] | Technology Adoption[a] | Regulatory Relations[b] |
| P1 | High | Emissions: ****<br>Waste: * | **** | Positive |
| M1 | High | Emissions: **<br>Waste: *** | *** | Positive |
| M5 | High | Emissions: ****<br>Waste: *** | *** | Neutral |
| M3 | Medium | Emissions: *<br>Waste: * | *** | Positive |
| M6 | Medium | Emissions: *<br>Waste: *** | * | Positive |
| M7 | Medium | Emissions: *<br>Waste: ** | ** | Positive |
| M8 | Medium | Emissions: ****<br>Waste: ** | **** | Positive |
| P4 | Low | Emissions: ***<br>Waste: * | ** | Neutral |
| P2 | Low | Emissions: *<br>Waste: *** | **** | Neutral |
| P3 | Low | Emissions: NA<br>Waste: *** | ** | Negative |
| M2 | Low | Emissions: NA<br>Waste: **** | * | Negative |
| P5 | Low | Emissions: **<br>Waste: NA | *** | Negative |
| M4 | Low | Emissions: *<br>Waste: NA | * | Negative |

a: **** = in best quartile for 34 metals and paints firms; *** = second quartile; ** = third quartile; * = worst quartile
b: **Positive** = the firm describes the regulator as a source of advice and support; **neutral** = the firm neither has regulatory problems nor expresses a positive perception of the regulatory relationship; **negative** = the firm has a significant burden of effort in dealing with prosecution and/or regulatory attention.

| Table 5: Environmental performance - average percentile rank by dynamic capability level | | | | |
|---|---|---|---|---|
| **Dynamic Capability** | **Emissions** | **Waste** | **Clean Technology Adoption** | **Overall** |
| **High** | 82% | 48% | 76% | 69% |
| **Medium** | 30% | 35% | 51% | 39% |
| **Low** | 20% | 37% | 39% | 32% |

**APPENDIX**: Case search routine and dynamic capability scoring.

*Notes for all Appendix tables:*
1. Scoring criteria for 'routinised search activity' are derived from Becker and Zirpoli (2008).

2. Scoring criteria for 'embeddedness of suite of search routines' – and hence for dynamic capability – are extended from Helfat and Peteraf (2003). 'Dynamic-capability classification' is assigned by the researchers based on the given assessments for these criteria.

| **Table A-1 Paint1** | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | A large number of planning projects initiated from time of licensing. HIGH |
| Use of data | In at least half of projects, environmental data used to help identify and evaluate alternative solutions. HIGH |
| Team problem-solving | Projects identified & developed at regular Safety-Health-Environment and Management committee meetings; further problem-solving in shop-floor committees. Many involve cross-functionality; e.g., a project including department heads from manufacturing, laboratory, and site resources. HIGH |
| External info sources | Many, e.g.: Clean Technology Centre in Cork, ISO 14001, EPA, parent- environmental and R&D functions, customers. HIGH |
| Use of outside expertise | Joint, collaborative, capability-enhancing. External-source expertise is input to the in-house project-advancement processes described above via extended collaboration. HIGH |
| *Embeddedness of suite of search routines*: *Durable*? Yes, extending over many years from time of licensing.<br>*Generalisable*? Yes, search processes extend across wide range of environmental issues.<br>*Integrated with management*? Yes, core management processes (SHE & Mgt committees, capital-budgeting) incorporate and facilitate environmental-management search.<br>***Dynamic-capability classification: HIGH*** | |

| **Table A-2 Paint2.** A small firm with a full-time environmental manager because of the severe and contentious environmental issues inherited at the plant site. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Environmental manager deals with environmental problems, conducts all related planning. Not collective. MEDIUM |
| Use of data | No evidence. LOW |
| Team problem-solving | No evidence. LOW |
| External info sources | Customers, suppliers. MEDIUM |
| Use of outside expertise | EM has worked with both customers and suppliers to make changes to the way raw materials and products are packaged, such as introducing reusable containers to save on disposal costs. MEDIUM |
| *Embeddedness of suite of search routines*: *Durable*? Likely vulnerable to tenure of environmental manager.<br>*Generalisable*? Little evidence of extended range of applicability of SRs.<br>*Integrated with management*? Limited to the EM function and solely his responsibility.<br>***Dynamic-capability classification: LOW*** | |

| **Table A-3 Paint3.** A small firm for whom is difficult to keep up with changes in legislation. The interviewee is also involved in quality control, colour matching, health and safety, problem solving etc.; the environment takes up approximately 2 hours a week of her time. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | No environmental planning, search-relevant or otherwise. Little to no awareness of waste streams or their sources. LOW |
| Use of data | No evidence. LOW |
| Team problem-solving | The technical department meets regularly for product development; employees are reminded that environmental issues must be taken into account. No evidence of cross-functionality. LOW |
| External info sources | Suppliers, re: the implications of legislative changes regarding raw materials; IBEC (Irish business association) courses; an environmental engineering consultant; firm's waste-disposal agent. MEDIUM |
| Use of outside expertise | Waste agent and consultant reports not followed up or implemented; IBEC trainers may be used one-off for advice. LOW |
| *Embeddedness of suite of search routines*: *Durable*? Neither recurrent nor institutionalised.<br>*Generalisable*? Little internal search capacity that could be generalised.<br>*Integrated with management*? Any environmental search that occurs is isolated in the person and function of the individual among whose duties environmental management resides.<br>***Dynamic-capability classification: LOW*** | |

| **Table A-4 Paint4.** A small firm; in addition to responsibility for environmental management, the interviewee also runs the colour lab and oversees quality. The environment takes up 30-40% of his time. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Despite greater priority to environmental issues, toward procedures to ensure noncompliances are not repeated, changes happen 'organically' rather than by plan. MEDIUM |
| Use of data | Sometimes uses data to drive improvement, as in an energy audit to identify trends and problem areas. MEDUM |
| Team problem-solving | The EM mainly works on the environment on his own, but others get involved if there is a problem or issue. No evidence of cross-functionality. LOW |
| External info sources | ISO 14001, implemented by consultants; consultants conducting an energy audit. LOW |
| Use of outside expertise | Disconnected from in-house search capacity. E.g., the ISO 14001 consultants wrote a very generic policy that formalised procedures but did not increase understanding or change day-to-day routines within the firm. LOW |
| *Embeddedness of suite of search routines*: *Durable*? Little institutionalisation, although environmental search has increased over time.<br>*Generalisable*? The search focus has been on a narrow range of cost-related waste problems.<br>*Integrated with management*? The EM works on his own; senior management is involved only in signing off on his decisions.<br>***Dynamic-capability classification: LOW*** | |

| **Table A-5 Paint5.** A small firm with an extremely adversarial relationship to the regulator. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Most environmental search-related activity appears to be conducted by the owner, and aimed at lowering the costs of various kinds of EPA-mandated monitoring. MEDIUM |
| Use of data | No evidence of data-use linked to environmental search. LOW |
| Team problem-solving | No evidence. LOW |
| External info sources | None reported. LOW |
| Use of outside expertise | None reported; the owner insists upon conducting the required monitoring and testing in-house, purportedly to maximise the learning and capability. MEDIUM |
| *Embeddedness of suite of search routines*: *Durable*? There is recurrent activity that is based in ownership/top management.<br>*Generalisable*? No: limited to after-the-fact monitoring and testing, not extended to learning and change in processes or products.<br>*Integrated with management*? Only in the sense of being exercised by ownership/top management. But search activities appear to be wholly separate from strategic, operational considerations.<br>***Dynamic-capability classification: LOW*** | |

| **Table A-6 Metal1.** Strengthened search routines in response to a prolonged crisis, when its unique production mix and sensitive local environment kept emissions above permitted levels and a technical solution to achieve compliance could not be identified. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | In anticipation of IPC requirements, explored a wide range of possible solutions, implementing a number of equipment and process changes. Ongoing trials of impact-reduction technologies. HIGH |
| Use of data | Many trials of technology options to solve difficult compliance problem, in concert with peer-firm and supplier collaborations. HIGH |
| Team problem-solving | A cross-functional team undertook the above. Now environmental improvement and progress is coordinated through monthly meetings of environmental team.. HIGH |
| External info sources | Similar firm in the US; centrifuge, UK micro-filtration, specialised waste recovery, and chemical supply vendors; two environmental consultants. HIGH |
| Use of outside expertise | US-firm technical exchange program, vendor relations, and consultancy use all integrated with and driven by own-firm search. HIGH |
| *Embeddedness of suite of search routines*: *Durable*? Search routines developed and refined over a period of many years.<br>*Generalisable*? Range of technical issues addressed, means of addressing them, and sources of expertise suggests wide applicability.<br>*Integrated with management*? Pushed by EPA-initiated legal actions to incorporate environmental search at all management levels. Vendor relations clearly involved heavily.<br>***Dynamic-capability classification: HIGH*** | |

| **Table A-7 Metal2.** The industry the firm is in (pressure vessels and tanks for pharmaceuticals, food firms etc.) is highly regulated internationally. The interviewee is the quality assurance manager for 2 firms and environmental manager for one. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Environmental management is undertaken as part of the quality assurance function, oriented towards compliance with externally defined standards. They do not actively look for projects; there is no evidence of a problem-solving capacity. LOW |
| Use of data | No evidence. LOW |
| Team problem-solving | No evidence. LOW |
| External info sources | External accreditation agencies; consultants. LOW |
| Use of outside expertise | Paid for an energy audit but made no changes. LOW |
| *Embeddedness of suite of search routines[2]: Durable*? Little sign of recurrent, institutionalised environmental search.<br>*Generalisable*? Insufficient routinised project-focused activity to support wide applicability of search capacity<br>*Integrated with management*? Almost wholly detached, in the person of the quality/environment manager.<br>***Dynamic-capability classification: LOW*** | |

| **Table A-8 Metal3.** A multi-site firm in the zinc galvanising industry. A full-time environmental manager for day-to-day issues reports directly to a senior manager, who was the interviewee. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | There are an environmental programme and team in place, which have tackled a range of process & waste technology issues. But projects often rely upon vendors or consultants rather than in-house goal setting, search, or assessment. MEDIUM |
| Use of data | Little evidence of collecting environmental data to drive improvement. LOW |
| Team problem-solving | A cross-functional environmental-management team. MEDIUM |
| External info sources | Consultants for specialised reports, monitoring; ISO 14001; vendors; Cleaner Greener Production Programme; peer firms. HIGH |
| Use of outside expertise | Consultant and vendor roles often eventuate in turn-key technology purchases. But ISO process was internally driven; Cleaner Greener participation led to new waste solutions; and in one case, a vendor proposal led to peer-firm visits. MEDIUM |
| *Embeddedness of suite of search routines*: *Durable*? Though delimited due to outsourcing, the noted search processes extend over many years and are well institutionalised.<br>*Generalisable*? Search capacity has developed over both production-process and waste-disposal projects. The focus on outside expertise and turn-key solutions is both a strength and a weakness here.<br>*Integrated with management*? The environmental manager works closely with his/her senior report, and they coordinate environmental improvement with general equipment upgrading.<br>***Dynamic-capability classification: MEDIUM*** | |

| **Table A-9 Metal4.** The interviewee is working as a consultant for the firm and is only there 1 day per week. He has responsibility for the environmental brief, but the onsite production and general managers have some input also. | | |
|---|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | | |
| Planning | Focus is on reporting and compliance only. | LOW |
| Use of data | No evidence; 'pretence' of an energy audit to satisfy EPA. | LOW |
| Team problem-solving | No evidence. | LOW |
| External info sources | The EM-consultant; Enterprise Ireland; energy-audit specialist. | LOW |
| Use of outside expertise | Simply to do reports. | LOW |
| *Embeddedness of suite of search routines*: *Durable*? Any search capacity is intermittent and fragile.<br>*Generalisable*? Insufficient activity to create a widely-applicable search capability.<br>*Integrated with management*? Intermittent and isolated from overall operating or strategic functions.<br>***Dynamic-capability classification: LOW*** | | |

| **Table A-10 Metal5.** A building products firm specialising in insulated outside cladding. Environmental search has waxed and waned with broader strategic goals, receiving intense focus during a cost-saving drive, and at the time of interviewing getting customer-driven priority to develop energy-efficient buildings. | | |
|---|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | | |
| Planning | Has used an established problem-solving process toward a variety of cleaner technologies: product changes, raw material substitution, recycling and reuse, and renewable energy generation. | HIGH |
| Use of data | A waste-management audit. | MEDIUM |
| Team problem-solving | Bi-monthly cross-functional teams and inter-departmental meetings in pursuit of the environmental search/planning, extending to the product-development function. | HIGH |
| External info sources | ISO 14001; EMAS (European environmental certification); customers. | MEDIUM |
| Use of outside expertise | Customer demand has been important, but overall, information on external Integration is limited. | LOW |
| *Embeddedness of suite of search routines*: *Durable*? Developed over many years and very institutionalised.<br>*Generalisable*? Widely applicable: search capability deployed across a range of problem and solution types.<br>*Integrated with management*? Yes, strategically central during repeated spans, although episodic.<br>***Dynamic-capability classification: HIGH*** | | |

| **Table A-11 Metal6.** A very small firm with one employee, the interviewee, responsible for IPC compliance and environmental management. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Planning as search is mainly driven by regulations but is extensive. The many projects include raw-materials substitution, waste handling, and product design. Emissions data is carefully collected and used to drive improvement. MEDIUM |
| Use of data | Trials to develop two specific lower-impact technology alternatives. MEDIUM |
| Team problem-solving | All decisions regarding environmental search have to go through the interviewee. Purchasing, shop-floor management and other functions involved as needed. MEDIUM |
| External info sources | Occasionally, suppliers and customers; Ecoland Project (the local University, a local state agency, and several small, local firms); EPA. MEDIUM |
| Use of outside expertise | Mostly to enhance internal capacity in a collaborative proccess. E.g., license review was of great benefit to the firm as they did it internally rather than using external consultants; learning was identified as a key benefit. HIGH |
| *Embeddedness of suite of search routines*: *Durable*? Environmental-search capacity built over time through recurrent activity. But its strength appears very much dependent on the energy and creativity of one employee.<br>*Generalisable*? Within a compliance-driven framework, search capacity applicable to a range of issues has been built. This had yet to be extended to forward-looking product and process change.<br>*Integrated with management*? The compliance focus limits integration of environmental search with strategic functions like product mix and capital budgeting; lack of institutionalisation leaves it dependent on one employee.<br>***Dynamic-capability classification: MEDIUM*** | |

| **Table A-12 Metal7.** A structural steel firm. The interviewee and a part-time assistant on the environmental brief are also responsible for functions like Health & Safety and Quality. | |
|---|---|
| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
| Planning | Firm recently instituted environmental and energy committees that meet every two months and use monitoring data to set targets and assess progress. MEDIUM |
| Use of data | These committees use monitoring data to set targets and assess progress. Several projects in EPA files indicate data used in search & assessment. HIGH |
| Team problem-solving | The EM uses ad hoc project teams to work on environmental projects when required. An *ad hoc*, cross-functional technical team working to address a specific EPA-targetted problem. MEDIUM |
| External info sources | Suppliers, Cleaner Greener Production Programme. MEDIUM |
| Use of outside expertise | The firm does not use consultants, as they prefer to work on solutions themselves and therefore learn new skills and keep new information and expertise in-house. HIGH |
| *Embeddedness of suite of search routines*: *Durable*? The number and frequency of environmental search activities are growing but still limited. Concrete steps toward institutionalisation are in the early stages and still emerging from the *ad hoc*.<br>*Generalisable*? The approach to environmental search makes it broadly applicable.<br>*Integrated with management*? Little evidence that the relevant search routines underway have yet embedded deeply in core organisational processes.<br>***Dynamic-capability classification: MEDIUM*** | |

**Table A-13 Metal8.** Subsidiary of a large tool-making firm. Much of their activity has involved resolving compliance issues. The interviewee is the engineering manager and he also has responsibility for environmental management.

| *Routinised search activity – Scored 'high-medium-low' by recurrence, collectivity, interdependencies-coordination* | |
|---|---|
| Planning | Apply previously-established problem-solving processes to environmental improvements: bi-monthly meetings to identify and progress projects. While search-related planning has engaged product and process improvement, much environmental project planning is remedial and compliance-oriented. MEDIUM |
| Use of data | Little evidence of data-based search. LOW |
| Team problem-solving | Bi-monthly meetings proceed via team-based work as possible. But an older, unionised workforce does not always co-operate. A cross-departmental team explored a major alternative-process change, including the interviewee, an engineer, the quality manager, the forge foreman and operators. MEDIUM |
| External info sources | A university research group, in conjunction with the Cleaner Greener Production Programme; customers and suppliers; consultants; and IBEC. HIGH |
| Use of outside expertise | Quite a bit of outside consultants usage on some projects, as an alternative to developing the expertise in-house. On the other hand, the CGPP-university group project proceeded collaboratively. MEDIUM |

*Embeddedness of suite of search routines*: *Durable*? Environmental search has been frequent and, in coinciding with general management routines, institutionalised. Yet environmental search routines in particular are vulnerable to being over-shadowed and, often, dampened by corporate-culture issues.
*Generalisable*? Both internal and external search has built environmental capacity that would be broadly applicable.
*Integrated with management*? The aim to work environmental and general efficiency initiatives in the same direction coexists with management's sense that the continuous improvement requirements of their IPC licence are onerous. Perhaps as a result, it was still uncertain the extent to which the relevant search routines would be integrated further with broader management processes.
***Dynamic-capability classification: MEDIUM***

**Dear Professor Verona,**

**Thank you for the opportunity to revise our "Identifying and measuring dynamic capability using search routines" (SO-16-0105)."**

**We are grateful to the reviewers for their high level engagement with the paper and their constructive feedback as to avenues for development. We really appreciated the high quality of the reviews, and the clear time and effort taken in reading and reflecting on our paper. We were encouraged by the reviewers' interest in our topic, empirical context and the aim of work. We have now revised the paper in the key ways you identified:**

**(i) the theoretical framing has been adjusted to provide more clearly novel contribution that builds on extant work.**
**(ii) we have provided more depth and clarity on our methodological approach.**

**We hope you will agree that in the revised version of the paper we have worked diligently to address all of the issues raised in the reviews and share our belief that the review process has sharpened the contribution of the paper. We have copied each comment from the decision letter and reviewer reports below and respond to each comment in bold.**

**Comments from Reviewer 1**

In this paper, the authors set out to bring greater clarity to the conceptualization and operationalization of dynamic capabilities—a key issue the dynamic capabilities perspective has been struggling with from its very inception. I agree with the authors that much can be gained from addressing repeated criticism regarding post-hoc identification of dynamic capabilities creating a tautology problem, that an approach to dynamic capabilities that emphasizes routines can be highly useful, and that we need more research that explores the intricacies of the DC-routine correspondence. I also applaud the authors for their interesting empirical setting (you don't see a lot of dynamic capabilities research in the context of governmental regulation changes) and for the multi-method approach they employ.

Yet, there are several areas for improvement. I elaborate on these issues below, starting with the issues that I believe are major and substantial and concluding with comparatively minor suggestions. I hope that my comments are helpful to the authors as they continue to work on the paper.

**Thank you for the time and effort invested in reading our paper and your encouraging assessment of our contribution. Your comments were very helpful to us in sharpening the contribution of the paper, and making the overall paper more directly focussed.**

1. Newness of contribution. While I applaud your effort to advance the routine approach to dynamic capabilities, I don't think you give enough credit to prior empirical work using a very similar methodology—most notably, Schilke (2014a, 2014b) and (Zollo & Winter, 2002). The omission of prior work makes your paper feel both more radical than it actually is and undersituated in the literature. It is thus important that you first acknowledge prior work advocating a routine approach to DC and then clarify how your study complements this stream. To be clear, I'm not saying that what you're doing has exactly already been done before. However, you need to be very explicit about how your work relates to earlier research efforts and what its more nuanced contributions are.

**Thank you for pointing out where we need to be more nuanced in positioning our paper and providing guidance. In response to this, we have both reframed the paper more carefully around where we have a novel contribution to make, and situated our work in the extant research.**

**The reframing is reflected throughout the paper, but is perhaps most succinctly seen in the new abstract, copied here:**

> *The dynamic capability approach is an important research area within strategic management. Much attention has been given to the theoretical and empirical difficulties of identifying dynamic capability, given that it is a latent or unobservable construct. Researchers in the field are now in agreement that dynamic capability should be defined so as to distinguish the capability for change from the change achieved, resolving a long debate in the literature. Less attention has been paid to how to operationalize this resolution.*

*Empirical work remains fragmented, limiting the coherence and therefore the development of the field. We draw on the concept of search routines from evolutionary economics to propose a measure of dynamic capability and demonstrate its application. We contribute to the dynamic capability field by presenting guidelines for identifying and assessing dynamic capability based on the underlying search routines, a method that is both sensitive to the specificities of dynamic capability in a given research setting and the need for coherence across the body of empirical work.*

**We situate our work in the extant literature in the introduction (pg: 2), in the paragraph copied below:**

*In both theoretical and empirical work, routines are accepted as a core component of dynamic capabilities. Despite this, routines are rarely used as the basis for operationalizing dynamic capability (Di Stefano et al., 2010; Grant and Verona, 2015). There have been notable exceptions; for example, Zollo and Winter (2002) and Schilke (2014) provide both early and recent examples of work where the measurement of search routines, routines for change and deliberate learning, have been used to research DC. It remains the case though that the field 'lacks generally accepted approaches to measure its key constructs' (Danneels, 2016: 2175).*

2. Contribution to length ratio. I do think there's a fine contribution to be made by this paper, but it may be a more focused one than what the paper currently promises (see my comment 1 above). This is not necessarily a problem if you are able to condense the paper further, thus improving its contribution to length ratio. There are probably different ways to do this, but one section that I believe has significant potential for saving space are the Findings. Eleven pages with descriptive details about the routines employed by the various firms in your sample are just too much. I mean, I understand that operationalizing DCs is at the heart of your paper, but going through this list is just very cumbersome. That's what your tables are for. Try to condense the key insights and most striking observations while referring the reader to the tables for more details.

**We have taken this observation on board and radically reduced the space given to the case stories by focussing on 3 exemplar cases, and created more meaningful tables (see Table 1, 2 and Appendix). The Findings section has been reduced from 3000 words to 1600 words.**

Moreover, I found your discussion of validity and reliability in the front end and back end (pp. 8-9 and 34-35, respectively) to be interesting but very redundant. Can you drop one of the two?

**Yes, thank you for pointing this out, we have confined this discussion of validity and reliability of the indicator to the Discussion, pages 29-30.**
**There is also a a discussion of how we ensured validity and reliability in our own research in the Methods section. These two discussions serve different purposes.**

3. Why only search routines? (a) In your lit review, you do a decent job in explaining why search routines are a good fit with DCs, but I still couldn't keep myself from wondering why it's only routines pertaining to search that matter. You should consider first adopting some established routine typology and then justifying why the other, non-search routines don't matter to DCs. (b) Similarly, although I am sympathetic to your routine-based approach, I felt that to the very least you need to mention alternative approaches to DCs—i.e., Eisenhardt's simple rules/heuristics and Winter's ad-hoc problem solving. We need to know why it's legitimate for you to bracket those in your paper.

**This comment proved very helpful and we have reflected it in a number of places. The literature review now contains a discussion of types of routines (pg.6), copied here:**

> *Nelson and Winter (1982) identify three types of routine. The first two are those routines that governing the short-run operating activity of the firm and routines for standard adjustments to operating activity in response to external conditions. In both these cases the outcome of performing the routine is known. They also identify a third type of routine, where the process is routinised but the outcome is not: 'the relatively constant dispositions and strategic heuristics that shape the approach of the firm to the non-routine problems it faces' (14). Nelson and Winter describe these as search routines, defined as 'the patterning of particular ways of attempting to innovate' (133) and 'routine-guided, routine changing processes' (18).*

**The literature review now contains a discussion of the ways in which change can happen without recourse to DC (pg.8), copied here:**

> *Dynamic capabilities are not the only way for an organisation to change. Deliberate learning may be routinised, the result of an investment to create and maintain processes for problem-solving but may also take place on a more ad hoc basis, as a one off response to an external change or crisis (Winter, 2003). Change may also be attributable to luck, accident or talented individuals more than a coordinated organisational response (Teece, 2012). We need a measure that can allow us to distinguish between these sources of change and separate out dynamic capability.*

**And the methods section contains the following amplification of what we mean by search routines (pg. 21):**

> *'The first step in creating search-routines (SR) data from the interview records was establishing a set of distinct (if inter-related) categories of search processes. Nelson and Winter (1982) argue that to change organisational routines at the operating level, search routines must enable the firm both to identify and to implement new or modified alternatives. What specific kinds of observable activities would be involved in locating, evaluating, and initiating action upon the information these firms needed, potentially from within and outside the boundaries of the organisation? In an iterative process between*

*the literature and the data, we chose the following search-activity categories:' [evaluative planning, use of data, team problem-solving, outside information sources, use of external expertise].*

4. Dynamic capability in what? I get that you would like to generalize your findings to all sorts of dynamic capabilities, and that's OK. But it is nonetheless important to note that there likely is no general dynamic capability that applies to all kinds of business activities for which change is critical (Gruber, Heinemann, Brettel, & Hungeling, 2010; Helfat & Peteraf, 2009; Helfat & Winter, 2011). Rather, dynamic capabilities are very context-specific and manifest themselves in various identifiable and specific business domains, such as CSR (in Aragon-Correa and Sharma (2003) as well as your study), but also new product development, alliancing, mergers & acquisition and so on (Eisenhardt & Martin, 2000). For example, a firm could plausibly have an awesome new product development capability while at the same time struggling with mergers & acquisitions. I believe it's important that you are clear about this and in the empirical section of the paper consistently label your DC as one related to environmental protection issues.

**Yes, we agree this aspect should be reflected in the paper. In trying to communicate the generalisability of our approach to measuring DC, we downplayed the need for specificity in a given research setting. We have brought this emphasis back in to the paper in two ways.**

**(i) Acknowledgement of specificity in the literature review (pg. 6)**

*Routines are seen as always specific to their purpose, and the idea of a general problem-solving routine is explicitly discounted (Winter, 2003).*

**(ii) A discussion of specificity in the methods sections (pg. 15 )**

*What specific kinds of observable activities would be involved in locating, evaluating, and acting upon the information these firms needed, potentially from within and outside the boundaries of the organisation? We emphasise the role of context-specificity (Helfat et al. 2007): cleaner-technology adoption requires management of specific information and skills in analysing alternatives, measuring results, and coordinating environmental strategy (Christie, 1995). In an iterative process between the literature and the data, we identified the following categories of processes aimed at search activity:*

5. What next? I was quite disappointed that you left us without any hands-on recommendations for how future DC work could adopt the routine approach advocated in the paper. How exactly do your findings change the way we should do research on DCs? This key question should be answered in the Discussion question. You may want to distinguish between qualitative research (e.g., how can we get at the details of how routines develop, are executed, and possible be abandoned) and quantitative research (e.g., how do we need to phrase questionnaire items?; what are concrete items you could recommend?; what are potential problems of self-reports/archival data in capturing search routines?). This is the place for you to move

beyond the mere fact that routines are relevant to give recommendations of exactly how to implement your advocated approach.

**In response to this comment we added a section in the Discussion as you suggest. In it we suggest three areas for extension of the approach: to other research settings (market, institutional, organisational), to focus in on one of the emergent themes in our findings (the importance of organisational integration), and to different kinds of DC-related performance (including sustainable competitive advantage).**

> *We focus here on three potential extensions of this approach. One would be adaptations of our SR and DC measure-construction steps to other settings. This process will identify problems with the approach, test the limits of its applicability, and (if warranted) refine it and make it a more robust and adaptable empirical tool of DC research. We would also see the method being developed though being applied to settings where different kinds of performance are at stake. In the present research context performance had to do with fitness and effectiveness with respect to a critical regulatory regime change. But learning, adaptation and resource renewal clearly affect any significant kind of performance. This could lead to applications where, like in ours, the performance dimension with related DC is rather specialised. The method could also, and clearly should, be tested in terms of the fundamental kinds of performance represented by sustainable competitive advantage and the generation of rents. Finally, a measure based on fine-grained activities allows for closer examination of how those activities interact and are integrated with their organisational setting. A long literature suggests that DC entails learning and knowledge creation (Argote and Miron-Spektor, 2011; Becker, 2005; Kogut and Zander, 1992; Winter, 2000), and that knowledge creation requires effective integration across the organisation's functions and individuals (Grant, 1996). Future research using our proposed measure could address the significant question of the role of knowledge and learning in dynamic capability development (Argote, 2011).*

6. Tacitness of DCs. The paper repeats several times that DCs are invisible. But if that's true, how come you were able to measure them? Intuitively, tacitness seems to defy measurability. That is, if something cannot be seen, how would you be able to measure it? I only started to figure this out on p. 36, where you first state that "(d)ynamic capability cannot be seen" but then claim that "(s)earch routines (…) can be observed." At this point, it came to me that DCs could be a latent construct that becomes measurable through routines, which serve as its observable indicators (e.g., Hult, Ketchen, & Nichols, 2002 on the latent construct logic). You might want to make this more explicit in your up-front theorizing.

**Thank you for pointing us to the latent construct approach, and helping us see the lack of clarity in our approach. We had discussed this without naming it as such in the first version of the paper.**

**(i) We have now been more explicit, using Hult et al (2002), the Godfrey and Hill (1995) paper they draw on, and the discussion on this approach in Grant and Verona (2015), see page 5 (copied below):**

> *However, while this decoupling of DC from performance avoids the problems of a circular theoretical definition, it still does not address the difficulty of operationalizing the dynamic capability construct in a non-tautological way (Arend and Bromily, 2009). Grant and Verona (2015) examine in more detail how the tacit nature of organisational capabilities in general and dynamic capabilities in particular makes this problematic. Dynamic capability is a form of unobservable (Godfrey and Hill, 1995) or latent (Hult et al., 2002) construct. The requirement then is to identify observable variables that can be credibly theoretically linked to the unobservable construct of interest. Some studies have relied on the relationship between antecedents of capability - such as experience or resource inputs - with performance, inferring the mediating role of capability, but unless alternative explanations for the relationship between antecedents and performance can be excluded, the credibility of the results remains in question (Grant and Verona, 2015). Other approaches suffer from problems of subjectivity and a lack of concrete evidence: measures that rely overly on self-reporting, such as by managers, or on the interpretation of the researcher without identifying the construct in a way that can be reliably repeated.*

**(ii) This is also reflected in the Discussion now (page 26), copied below:**

> *We identify DC conceptually as 'latent action' (Di Stephano et al. (2014:), then observe and measure it from routinised search processes.*

7. Where is your paper going? I was somewhat surprised to see you move to the Research Design section (p. 10) without having developed some sort of hypothesis or proposition, or to the very least a concrete research question that you derived from your lit review and then set out to test in the empirical study. I suggest you move the research question from p. 16 to the end of your lit review section.

**Yes, we can see now that the research question comes far too late. We have now moved it to the introduction (page2).**

8. Front-end back-end fit. It is interesting to see that you first criticize "measures that rely overly on self-reporting" (p. 7), but then go on to use "mail-out questionnaire" and conduct "in-depth interviews" (both p. 12) yourself. This seems inconsistent. Either drop the self-report criticism or don't use self-report data.

**Thank you for finding this inconsistency. The questionnaire was used in another phase of the research and the data are not relevant here, we have removed all references to this data source.**

9. Design of the tables. Table 1, as it is structured currently, is quite unwieldy. Rather than repeatedly listing the same indicators as bullet points, transform them into separate columns and code each firm for the presence/absence of each indicator. This will make it far easier to see how you arrive at the composite (environmental

protection) DC measure. You can also condense Tables 2 and 3 further by using a similar approach.

**In response to this comment, we have restructured the tables to make the development of the measure clearer. Thank you for providing the reader's perspective on how to better present this information.**

**Comments from Reviewer 2**

My reaction and expertise

Strengths
Here are some points that stand out about the paper:
1. You are drawing on a rich data set, containing both quantitative and qualitative data.
2. The Irish regulatory environment provides an interesting and unique setting.
3. There is an interesting connect between one of the world's most pressing issues, i.e. environmental damage, and the strategy literature.
4. You are using a fairly strong literature base.

Weaknesses
These are perceived shortcomings:
5. Overall, the literature you used is solid. However, you are missing a couple of more recent theoretical pieces (Di Stefano et al., 2014; Peteraf et al., 2013) which do call into question your claimed contribution.
6. I do not feel that the "search routines" you identified are really higher order capabilities. To me, they more accurately reflect a set of measures and protocols.
7. Although your data set is interesting, there are a number of methodological flaws that diminish the credibility of your claims. These should be addressed.

In my opinion, the paper can benefit from addressing the above and other issues; you may do so by considering the suggestions listed below:

**Thank you again for your time and effort in reading and commenting on our paper. Your constructive comments have challenged us to revaluate these issues that we may not have emphasised clearly enough in the first version of the paper. We hope you agree these are now more visibly articulated in the current version of the paper.**

Introduction
8. The introduction should be revised. I recommend the following structure to improve the readability and the logical flow (current status in parentheses):
a. Motivation of the topic (questionable, see theoretical foundations)
b. State of the art in literature regarding the topic (questionable, given a)
c. Gaps in literature (questionable, given a)
d. Research question based on gaps (not present)
e. Procedure to answer the research question (not present)
f. Expected contribution to theory and practice (questionable, given a)
g. Description of the structure of the paper (okay)

**Thank you for this helpful structure. In response to this comment, we have rewritten the introduction following this suggestion, we feel it brings out the**

**purpose of the paper more clearly now, and should help the reader understand our purpose more easily.**

Theoretical Foundations:

9. You base your paper on the tautology trap plaguing dynamic capabilities research. Given the more recent works on this topic, you may not address a relevant gap here. Peteraf et al. (2013, p. 1402) note: "While there was a question about whether TPS's conceptualization was tautological (Eisenhardt and Martin, 2000), this issue has since been answered satisfactorily (e.g., Helfat and Peteraf, 2009; Helfat et al ., 2007)". In another piece, Di Stefano et al. (2014, p. 316) add: "At one end of the spectrum of views, there are those who hold that dynamic capabilities necessarily provide firms with a competitive advantage. This, however, is not a matter for debate, but only a matter of confusion, in that it produces the same tautology of which the resource-based view has been accused (e.g., Bromiley & Fleming, 2002). Whether a specific dynamic capability is capable of creating value, providing a competitive advantage, or generating rents depends on a set of conditions that Helfat and colleagues (2007) described concisely. Advancing the level of understanding within the field concerning these issues depends on a more uniform use and better understanding of various performance metrics (Peteraf & Barney, 2003)." I think the above statements take away the key motivation for your paper, your gap, and your contribution. If not, you should connect to these references and explain why that is not the case.

**We have reframed the paper more narrowly around the need to operationalize a measure of DC that reflects the Helfat definition. The reframed abstract is copied here:**

> *The dynamic capability approach is an important research area within strategic management. Much attention has been given to the theoretical and empirical difficulties of identifying dynamic capability, given that it is a latent or unobservable construct. Researchers in the field are now in agreement that dynamic capability should be defined so as to distinguish the capability for change from the change achieved, resolving a long debate in the literature. Less attention has been paid to how to operationalize this resolution. Empirical work remains fragmented, limiting the coherence and therefore the development of the field. We draw on the concept of search routines from evolutionary economics to propose a measure of dynamic capability and demonstrate its application. We contribute to the dynamic capability field by presenting guidelines for identifying and assessing dynamic capability based on the underlying search routines, a method that is both sensitive to the specificities of dynamic capability in a given research setting and the need for coherence across the body of empirical work.*

10. Having said that, I think positioning the paper around the strategy literature that focuses on environmental issues, CSR, and ethics may be smarter move and make the re-positioning of your paper feasible (Aragón-Correa & Sharma, 2003; Arend, 2012; Eccles et al., 2014).

**We can see the value of connecting our work to other strategy work on sustainability, and thank for the suggestion which gives us an avenue to explore in future work. On reflection, our judgement was that it would not be feasible to reposition the paper so radically for a resubmission to SO! Given the constructive advice from you and the other reviewers, we are confident that we can reframe this paper more carefully around our original purpose and use our research to make a contribution to the general DC literature.**

Method:

11. Nowhere from pp. 10-12 do you specify what this type of research classifies as. If I were to give it a name, I would call it a multiple case study. If you agree, why don't you set the method section up that way? Yin (2009) may be a good starting point for this.

**In response to this comment, and your other comments on our methods section, we have deepened the discussion of method, including being more explicit about naming the design as a multiple case study.**

12. As for sampling: On p. 12, you write that "case firms, five from the paint and ink sector and eight from the metal fabricating sector, were selected on the basis of maximising our opportunity to learn (Stake, 1994), and so were chosen for variation in environmental practice and outcomes. Furthermore, "to help better understand the role of dynamic capability in this transition, we also conducted in-depth interviews with managers at 13 companies." This does not sound very convincing. First of all, the IPC affects at least nine industrial areas (http://www.epa.ie/licensing/ipc/whoneedsalicence/). Given this fact, I wonder why you've only included three of these.

**There is a long answer to this, some of which is contained in an earlier paper, and some of which we have now added to the methods section. We needed to be able to select groups of firms that were similar in the technologies they employ and the environmental emissions they are regulated on. Otherwise the opportunity for comparison is lost in the noise created by different permitting conditions and technological solutions.**

**The EPA does organise its licensing under 9 areas of industrial activity, but these are not determined by standard industrial activity classification (NACE codes). They are determined by mixture of key environment impacts and 'similar' industrial activity. For example EPA define class 8 activities (Wood, Textiles, Leather) to include 10 different types of industrial activity including: manufacture of synthetic fibres, tanning of animal hides, and production of fibreboard. Firms in these 3 areas of industrial activity cannot meaningfully be compared. Our initial challenge was to map the 9 classes onto the national NACE data to find sub-clusters of firms that were both a coherent industrial category and subject to IPC licencing. The 3 classes we looked at were the most viable given these considerations, and the sampling criteria below. The relevant extract (page 11) from the Empirical Research Framework is coped here:**

*In a broader project (Authors, 2011), we explored IPC-driven technological and managerial practices and pollution-level outcomes among 59 firms in three Irish industry sectors: metal fabricating, paint and ink manufacturing, and wood sawmilling and preservation. We chose these sectors three reasons. First, for generalisability, we sought sectors exhibiting a range of technology, product and market characteristics. Second, we favoured industries with a high percentage of single-facility firms, where facility-level environmental data would match with firm-level financial data. And finally, we avoided sectors subject to substantial transfer-pricing bias due to facility 'sales' to same-firm subsidiaries elsewhere.*

I do think that sampling for variation has great value in this context, however you would need to make the process transparent and explain the criteria in more detail. For example, given that you have access to the EPA audits, you could potentially select a high performer and a low performer from each industry and then compare and contrast them. In this context, I've found the chapter by Langley and Abdallah (2012) extremely useful. You may want to consider the "Eisenhardt template".

**This comment confirms that our approach is right, but we have not communicated it properly, thank you. We used our environmental performance data to choose high and low performers. We believe this is now clearer in the paper (see Sample Selection, page 12) Thank you for pointing us to the L&A chapter, which has proved valuable; we have used it especially in the discussion of validity and reliability (pages 19). As you identify, the Eisenhardt template closely describes the approach we took, and in response we have reflected this in the new Methods and Findings**

13. You mention on several occasions that you have access to a rich data set, comprising quantitative and qualitative data. In the method section you should make sure that the reader gets a good idea of what exactly you have. Normally, tables are included in qualitative papers that list the different sources and quantity of evidence. You could also consider putting some overviews in the appendix or submit it as supplementary material. Check Miles and Huberman (1994) for inspirations.

**We have expanded our description of the EPA data-sources and how they were used in the study. We also refer the reader to more full discussion in our prior published research.**

14. I am not convinced by the steps you take for identifying search routines on p. 15. I believe it is advisable to add a section on search routines in the theory part of the paper already, given that you even include the term in the title of your paper. For example, Felin et al. (2012, p. 1356) write that "Nelson and Winter (1982) distinguish routines from search routines where the latter are routines that serve to change lower-level routines (a precursor of the notion of dynamic capabilities)". Moreover, Felin and colleagues put forward so-called microfoundations of dynamic capabilities. These are individuals, processes, and structure. These three categories may also be useful to structure your "search routines".

**We can see now that there is a gap in the paper where the discussion of search routines needs to be expanded. We chose not to follow the micro-foundations approach as that would take us into a different level of analysis, and we believe the routine is the appropriate (observable) unit of analysis. In response to this comment:**

**(i) There is an expanded treatment of search and search routines in the Literature review (page 6-8).**

**(ii) We have added some deeper discussion also in Case Data Protocol: Search Routines (pages 14-).**

15. There is not a single word on data analysis. However, there should be a whole section. How did you come up with the classifications? What exactly did you do? What recipe did you follow? Please check Miles and Huberman (1994) for different analytic options.

**Thank you for this guidance and identification of this gap. The data classifications and 'recipes' for construction/scoring now appear in the section Case Data Construction (pages 15-).**

16. In order to ensure rigor in your case study research, you should have a look at Gibbert et al. (2008) and follow the procedures suggested in the article.

**Thank you for suggesting this very helpful article. We have used it especially in the Methods section looking at validity and reliability, pages 19-20, copied here.**

> *Validity and Reliability*
>
> *Well-known shortcomings of case studies (Miles and Huberman, 1994) can be mitigated with care to ensure validity – empirically representing the key characteristics and relationships identified in the theoretical concept – and reliability – avoidance of excessive researcher subjectivity that could endanger replicability across researchers and settings.*
>
> *We use a set of validity definitions from Gibbert et al. (2008). Construct validity refers to 'the quality of the conceptualization or operationalization of the concept' (1466). Our empirical SR categories and DC measure were defined and constructed in careful relation to definitions in the literature. We employed a broad view of 'search,' consistent with Nelson and Winter (1982) and Teece (2007) among others; our definition of 'DC' follows Helfat et al. (2007: 4) by focusing on a firm's 'capacity… to purposefully create, extend, or modify its resource base.' We think it reasonable to argue that the search activities as observed, categorised and scored, and used in combination as assessed, would contribute to that capacity.*
>
> *Internal validity requires logically persuasive reasoning in applying the constructs during data analysis (Gibbert et al., 1466). During cross-case analysis as reported in the next section, we carefully allowed for the possibility of alternative sources of environmental performance other than*

*DC. We also noted the consistency between our findings as analysed and those expected from a reading of the literature.*

*Finally, external validity refers to the analytical generalisability of the method and conclusions to other settings (Gibbert et al., 2008: 1468). We have sought to ensure this by means of careful and transparent sample selection at the start and cross-case analysis at the end of the case protocol (Langley and Abdallah, 2011).*

*Issues of generalisability and transparency are related to the need also for reliability: a minimum of subjective inference by the researcher, to enhance replicability across researchers and/or different data applications with consistent results (Gibbert et al., 2008; Seale, 1999). Our study supports replicability by adhering to an accepted protocol (Eisenhardt, 1989; Langley and Abdallah, 2011). The protocol includes clear and simple principles for case selection, data construction, and analysis. Researcher subjectivity at the critical case-information collection stage is reduced by means of multiple interviewers, audio recording, and rapid write-ups. Replicability is especially important in this instance, because the essence of the research question is whether the proposed method provides an applicable operationalisation of a well-known theoretical proposition.*

17. In the first sentence of the findings section, you spell out your research question. I think you should have included it in the introduction already.

**Yes, you are right, it has been added now to page 2.**

18. Table 1, 2 and 3 are all introduced in one paragraph on p. 16, without developing the story for them. This is like dumping your results on the reader at once. Why don't you guide the reader through your tables one by one, explaining what is contained in them and what the reader should take away from them. Again, you may benefit from Langley & Abdallah (2012). A systematic presentation of tables and overviews can really help you to convey your findings.

**Thank you for identifying how the reader may struggle here due to poor clarity. We have reformulated the tables and have taken more care in introducing them.**

19. In your findings, I would like to see more use of the data collected. For example, at this point I still have no idea what the EPA audits contain. Moreover, every case should be accompanied by a sample citation and possibly other evidence you collected.

**The methods section gives more detail on the data sources, and also explains the role of the EPA data in data triangulation.**

20. I would urge you to consider dropping one of the dynamic capability dimensions, reducing them to three. I would imagine that a high, medium, low matrix is complex enough.

**You are right. In response to this comment we have consolidated the DC dimensions into three.**

21. Table 1 is interesting and probably the core of your findings. However, in its current stage it is a collection of activities. I wouldn't necessarily call them search routines. In addition, some of these activities co-occur, others are idiosyncratic to an organization. I would like to see an attempt to classify and structure these activities a bit more (see suggestion in comment number 14). Are there any patterns among the dynamic capabilities categories, or among industries? These kind of insights could make the paper substantially more interesting and perhaps help with your contribution.

**This table has now been eliminated in conjunction with the reorganisation of our entire Methods and Findings sections. The relationship between the reported activities and search routines is drawn out in the section on *Case data construction*, pages 15-18. Much of the company-level detail that was distracting to reviewers has been moved to a set of Appendix tables which can be included with the paper or as Supplementary Material. The patterns in the data are now analysed explicitly in section Dynamic Capability and Performance, pages 24-.**

Discussion/Conclusion

22. On p. 29 you write that "In complying with the introduction of IPC environmental regulation in Ireland, firms had to learn to do new things, achieve technological and managerial change, and keep detailed records from which fine-grained information about the learning processes can be inferred." Unfortunately, I don't see this data anywhere. It should have been presented in the findings section.

**This data is presented in the case stories of the three exemplar cases, as the search routines we identified in each firm. See page 21-22 and page 23-24 for these cases.**

23. In its current form, there is no contribution. Admittedly, on p. 36 you do state that "our findings suggest that this approach can support an ordinal dynamic capability measure that is theoretically valid and empirically reliable and robust. Because it is based on clearly-defined, concrete activities, it may also be of use to practitioners seeking to manage organizations in changing competitive environments". There are several problems with this claim. I actually disagree that you've developed a measure. There is no scale and no list of items that other researchers could use to test for dynamic capabilities. Yes, you do list some activities, but to get from activities to a measure, there is still a lot of work to do, let alone to test for a robustness of that measure (e.g. Danneels, 2015). Whetten (1989) may prove useful for the revision of this section.

**We have now framed our contribution as a workable way to operationalise Helfat et al.'s (2007) theoretical solution to the tautology problem: to develop an observable process-based measure to represent the latent, unobservable DC concept. The steps in going from activities to the measure now are detailed carefully in the section Case Study Data on Search Routines and Dynamic Capability (pages 14-17).**

**Comments from Reviewer 3**

This manuscript reports a qualitative analysis that explores organizational search routines as an indicator of dynamic capabilities (DC). The central proposition of the research is that empirical exploration of DCs is subject to the "tautology problem," where DCs are identified by the high performance that they are theorized to produce. I thought this was a well-written paper that reported a careful analysis. I am certainly encouraging of work in this domain.

**Thank you for the detailed and constructive feedback you have provided in your review process and the positive encouragement you give to our work. We very much appreciate the time and effort you have invested in our paper.**

1) I have to admit that as a resource-based theorist and someone who has done a bit of work in the DC literature, I have grown weary of the "tautology" critique. Helfat et al. (2007), which is cited considerably here, established a theoretical framework for DC that (should have) once and for all put to rest the well-worn tautology argument. Accordingly, I would encourage you similarly to put that framing to rest. I'll note that doing so does not, in any way, require you to adapt your core contribution. You can still frame search as an indicator of DCs (but see Comment 3): simply work more closely to Helfat et al's (2007) arguments about "fitness." You can demonstrate how DCs relate to fitness (I think; See Comment 5). In any event, I believe the tautology framing is a bit of a red herring: you make an interesting contribution with the work on search … why invoke the tautology argument and distract the reader?

**We have followed your advice and moved away from the tautology framing to refocus on search as an indicator of DC. The revised abstract is copied here:**

> *The dynamic capability approach is an important research area within strategic management. Much attention has been given to the theoretical and empirical difficulties of identifying dynamic capability, given that it is a latent or unobservable construct. Researchers in the field are now in agreement that dynamic capability should be defined so as to distinguish the capability for change from the change achieved, resolving a long debate in the literature. Less attention has been paid to how to operationalize this resolution. Empirical work remains fragmented, limiting the coherence and therefore the development of the field. We draw on the concept of search routines from evolutionary economics to propose a measure of dynamic capability and demonstrate its application. We contribute to the dynamic capability field by presenting guidelines for identifying and assessing dynamic capability based on the underlying search routines, a method that is both sensitive to the*

*specificities of dynamic capability in a given research setting and the need for coherence across the body of empirical work.*

2) For me, the most conspicuously absent component of your theoretical framing was a more complete and robust integration of the LARGE literature on organizational learning. I am entirely persuaded that search is a component of DCs. So then why not leverage the large literature in the behavioral tradition on search and learning? For example, you cite Zollo and Winter (2002) … so you could incorporate perspectives on experiential versus deliberate search. But that's just the beginning. Levitt and March (1988) provide a seminal description or organizational learning, and many perspectives in their work relate to search. And, of course, there is a large component of search embedded in the HUGE exploration and exploitation literature (starting with March (1991), but it's a huge literature … Benner and Tushman (AMR 2003) comes to mind), as well as the performance feedback literature (e.g., Greve, 2003). Now I don't think – or expect – that you would be able to integrate all of this scholarship: you should leverage only those theoretical perspectives that make your learning story more theoretically robust. My point is that there is a very large literature on learning through search that you do not integrate, and it is conspicuous in its absence.

**As you say, organizational learning is a closely related field, and a large one. We are aware of Argote's (2011) call for more work in OL to look at dynamic capability. We have reflected the shared intellectual heritage of DC and OL in a deeper treatment of search that goes back to the origins in behavioral work (Cyert and March; Simon), see page 7 and copied below:**

*The concept of search routines draws directly on the work of Cyert and March (1963, 1992) and their concept of search. Organisations face bounded rationality and imperfect information. Rather than optimising behaviour, firms take satisficing decisions according to heuristics and rules of thumb. Rules evolve over time, so act as carriers of prior experience and learning. Higher-level rules guide the modification of lower level rules, often prompted by failure of an existing rule (Cyert and March, 1992). The classical notion of search (Simon, 1955, 1956) involves the creation of potential solutions, not just the discovery of a pre-existing set of alternatives. These can typically can only be assessed/selected in an experiential manner (Gavetti and Levinthal, 2000) through real world trials of proposed solutions (Winter, 2000) Goal setting is part of search, used to frame the problem to be solved (Nelson and Winter, 1982), and also in establishing aspirations which motivate the search activity, such as routines for benchmarking (Winter, 2000). When the solution is deemed satisfactory, search stops and the new solution becomes fixed as a routinised process. 'Search' therefore encompasses search, selection and implementation of new ways of doing things. This corresponds directly to the theorised functions of DC as search, selection and deployment which similarly will be found not as general dynamic capabilities for change but as particular dynamic capabilities for specific change purposes (Helfat et al. 2007).*

3) The DC literature is fairly well developed, and so qualitative theory building work seems to have higher hurdle to cross. Do not read that as suggesting I'm hostile to your empirical approach: I'm not. I do think it means that you need to be clear on where you are making a novel theoretical contribution/extension to the theory. As my prior comment suggests, I think it's in the area of integrating the search and learning literatures more fully: that would be a substantive and important contribution. Indeed, I think this is a more interesting contribution than framing search as an indicator variable for DCs, which I found to be a fairly pedantic point. It would be more impactful to argue that DCs necessarily involve a search mechanism and you are unpacking that component mechanism. This would make insights like those in the middle of p. 8 ("search routines … are a necessary element … of dynamic capabilities") much more impactful. If you go in this direction it seems that your paper should then offer propositions and/or research questions to direct future empirical work that can build on the conceptual ground you cover.

**We can see the value of integrating search with learning, given the Argote call, and thank you for the suggestion which gives us an avenue to consider for future work. We have acknowledged this in the conclusions. We felt that it would not be feasible to reposition the paper so radically for a resubmission to SO! Given the constructive advice from you and the other reviewers, we are confident that we can reframe this paper more carefully around our adapted contribution. We suggest for future work that the fine-grained detail that our measure allows for would be suited to exploring the role of learning and knowledge in DC.**

4) With regard to your analysis of search routines: I was confused by some of the evidence you marshalled as support for search. You summarize your evidence in Table 1. Is using goals really search? It certainly does not seem to be search in the same as, say, accessing external advice may be search. So this relates to Comment 2: can you leverage some of the existing search literature to motivate why and how the behaviors you observed were, in fact, search?

**Thank you for pushing us to greater precision here. We have leveraged search literature to discuss the type of goal setting we mean, and why this is a part of search. The types of goals are firms are setting are not goals that are set within a project to measure progress but rather benchmarking or stretch goals set to frame and stimulate the development of new projects. The relevant section from the literature review (page 6) are below.**

> *Goal setting is part of search, used to frame the problem to be solved (Nelson and Winter, 1982), and also in establishing aspirations which motivate the search activity, such as routines for benchmarking (Winter, 2000). When the solution is deemed satisfactory, search stops and the new solution becomes fixed as a routinised process.*

**The relevant section in the methodology section is Case Data Protocol (page 15) is copied here.**

*1. Planning. This relates not to 'planning' qua orderly execution of pre-determined activities, but rather to processes for the purposeful organisation and processing of the search for information while evaluating possible courses of action. An example is a regular planning group that meets to scan for future needs, set environmental priorities and commission specific search projects.*

5) My recommendations that you cut the tautology framing notwithstanding, I did find it odd that after arguing that we don't need evidence of performance to establish the presence of DCs (which I agree with and that's fine), you seem to spend a good bit of time on linking the presence of DCs with performance outcomes (e.g., Table 2). Now, to be fair, I may have missed something here … I found this section of the paper (pp. 27-28) fairly unclear. However, I wonder if you might not be better off reframing the arguments here in terms of "fitness" (ala Helfat et al., 2007). It seems to be that what you are describing is really more like evolutionary fitness than "performance."

**In response to this comment we have tried to be clearer about the role of performance in our argument. We use an independent measure of performance to show how you can be more precise about the relationships between DC and performance when you measure them in distinct ways. We need the performance measure to show that while DC is generally linked to higher performance, there are outlier cases where DC does not deliver performance, and cases where performance is not driven by DC. We think the rewritten case stories will draw this out; see especially pages 21-24.**

6) I am troubled (considerably) by one aspect of your framing. Namely, I read the dynamic capabilities literature as focused on organizational routines to (re)configure the firm's resource base in response to environmental changes. As Helfat et al (2007) note, and you cite (p. 6): DCs are "the capacity of an organization to purposefully create, extend or modify its *resource base* (emphasis added). It does not appear that the changes you consider here are, in fact, resource-level changes. So I wonder if you are really examining dynamic capabilities, or rather (just) organizational search and learning. To be clear: I would be fine if it was only the latter. I think you need to be clearer on why and how these are dynamic capabilities if there is no resource change. If you disagree, please help me understand what I'm missing.

**From Helfat et al.(2007: 6): 'The "resource base" of an organization includes tangible, intangible, and human assets (or resources) as well as capabilities which the organization owns, controls, or has access to on a preferential basis.' So by creating new technical capabilities, our firms are extending their resource base. In response to this comment we have tried to be more clear about this throughout, see especially (page 28 )**

*The outcomes of the search routines employed by the higher-DC among these firms were new assets and capabilities in environmental impact-reduction. These included cleaner technology capabilities and assets; long-term market*

*relationships with suppliers and customers; and lasting organisational systems and knowledge.*