TACIT KNOWLEDGE AND DYNAMIC CAPABILITY: THE IMPORTANCE OF PENROSIAN 'IMAGE'

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Introduction

The origins of dynamic capabilities have been neglected. Questions about the balance between the tacit and inimitable elements of capability and the role of intentionality require further exploration. Undoubtedly some of these questions remain open because of the paucity of empirical work (Foss, 1996; Cohen et al., 1996; Zollo and Winter, 2002). This is compounded by the finding of Becker (2001) that there is very little integration of empirical findings back into the theoretical debates, notwithstanding that many of the questions raised are not amenable to being answered by theory alone. This paper attempts to address some of these questions by providing empirical work on the nature and impact of dynamic capability that is explicitly rooted in the existing theoretical literature.

Earlier research established the role of organisational capabilities in explaining successful firm adaptation to a changed regulatory environment (Hilliard, 2002, Hilliard and Jacobson, 2003). Significantly the research identified the key role of dynamic capabilities in adaptation; the presence or absence of appropriate static capabilities, either technical or managerial, did not matter if firms possessed dynamic capability. In this paper the focus is on unpacking the nature of dynamic capabilities through a cross case comparison of five firms that display either strong or weak dynamic capabilities. The intention of the case study approach is to gain insight into the evolution of organisational capability without abstracting away from context-specific factors. As well as drawing out the development of capability, the cases also focus on the importance of capability in determining the firm's effectiveness in adjusting to the new regulatory environment. In each case evidence of routines underpinning dynamic capability is examined.

I find that the nature of the firm's perception or image has an influence on the presence or absence of reflexive and deliberative processes of learning and change, resulting in the failure or success in developing capability and achieving effective performance. It is therefore argued here that dynamic capability is a function of both the tacit perceptions held by a firm (arising out of past experience and learning) and deliberative, problemsolving processes. This represents a refinement of existing approaches to dynamic capability, and argues for increased importance to be given in research to the

role of firm perceptions.

The theory of dynamic capabilities

Evolutionary economic theory takes the firm as its unit of analysis, with the proposition that organisational capabilities are central to an understanding of firms and industries. Routines define what the firm can do, they are akin to the skills of the firm and they form the building blocks of the firm's organisational capabilities (which define what the firm has the potential to do). Nelson and Winter's developed the concept of a routine, defined as 'all regular and predictable behaviour patterns' (1982, p. 14). Routines cover activities 'that range from well-specified technical routines for producing things, through procedures for hiring and firing, ordering new inventory, or stepping up production of items in high demand, to policies regarding investment, research and development (R&D), or advertising, and business strategies about product diversification and overseas investment' (ibid., p. 14). Variation, or firm differences, stem from two sources: the effects of random events ('the timely appearance of variation under the stimulus of adversity' (ibid., p. 11)) and routines for deliberate learning. Nelson and Winter define an activity of 'search': 'routine-guided, routine changing processes' (ibid., p. 18) which are themselves routines that 'operate to modify over time various aspects of [firms'] operating characteristics' (ibid., p. 17). Following Penrose's (1959) conception of the learning firm this search process is shaped by the firm's heterogeneous bundle of resources and so will have a unique outcome. 'Search and learning lead to what ex post may be considered differential 'fitness'' (Dosi and Nelson, 1994, p. 160). In summary, the firm in Nelson and Winter's theory is one whose possible behaviour is determined by its set of routines. This view identifies 'the routinisation of activity as the "locus" of operational knowledge in an organisation' (1982, p. 104). Routines function as durable storage for non-codified knowledge, allowing for the preservation of knowledge as well as its effective use.

Differences in routines, reflecting different experiences, result in differences in the behaviour of firms. The competitive environment acts *ex post* as a selection mechanism. Where differences in behaviour are responsible for competitive advantage they lead to

differential rates of growth and survival. The concept of organisational capabilities1 was established by Edith Penrose (1959) in her influential work *The Theory of the Growth of Firms* and has provided inspiration not only in evolutionary economics but also in strategic management and the development of the competence-based view of the firm. Penrose sees each firm as being a unique bundle of heterogeneous, organisational capabilities; these capabilities are derived from resources, both physical and human. The firm acquires resources but makes use of the *services* of those resources - this distinction is important because one resource may provide many different services, depending on the circumstances of its use, and the knowledge of the firm using it. As the firm's circumstances change, most importantly through experience and growth of knowledge, the possibility arises that it will develop new services from existing resources. Organisational capabilities are the basis of firm uniqueness.

In the Penrosian model of growth the crucial capability is managerial capability, which has an entrepreneurial element that drives growth and an administrative element that ensures the implementation and integration of growth plans. Managerial capability also determines the value of the firm's resources. The value of any resource is specific to the organisational capability bundle that it is part of; this means that, unlike in the neoclassical model, the value of a service does not necessarily equal its market price, nor can it be equalised across firms. Management's valuation is shaped by their learning experiences of past growth. Their perception of risk and of future productive opportunities is shaped by past experience. These combine to form the 'image' that management has of the firm's opportunities for and limits to potential, future growth.The firm is a learning firm, where the value of organisational capabilities is not static but is affected by the dynamic processes of firm learning and growth. Managerial resources benefit from learning: development comes from experience, from new challenges provided by growth, from teamwork within the firm and from new skills. The enhanced productivity of the management resource is then employed to enhance the use of other resources. Penrose's conception of knowledge has a lot in common with work done by Polanyi (1966) on *tacit knowledge*. Tacit knowledge is that part of a person's skill that is

not easily[1] communicated, that cannot be codified or written down. Tacit knowledge can be hard to observe, to the point that even the people who possess it may not be aware of the fact. It is often context-dependent, such as knowledge developed through problem-solving in a

specific organisational context. This means that although knowledge may reside in people it can only be articulated within the organisation - this is how Winter can say that 'firms are organisations that know how to do things' (Winter, 1988, p.175). Tacit knowledge is hard to replicate or imitate. If it can be transferred at all it is only through teaching by example, and then this is only the case with knowledge which is observable. This is what makes an organisational capability into a source of sustainable competitive advantage. The cumulative nature of much knowledge, built up by experience and time is both a source of firm uniqueness and a barrier to imitation. It can also act as a constraint on the firm, as path-dependency can become sub-optimal lock-in.

It is clear that within evolutionary economics the development of the firm is seen as being strongly path-dependent. Teece et al. (1994) argue that the future direction of the firm is partly a question of the technical opportunities open to the firm. These may be the result of internal innovation, or they may be developed externally to the firm through developments in basic science or by other firms. In either case however, the exploitation of these opportunities by the firm relies crucially on its 'knowledge base and organisational context' (Teece et al., 1994. p. 16), that is, on the firm's capabilities. The technical opportunities that the firm is best able to explore will lie thus 'close-in' to existing technologies used by the firm (Teece and Pisano, 1994, p. 546). This is reinforced by the fact that 'in addition, a firm's past experience conditions the alternatives management is able to perceive' (Teece et al., 1997, p. 524), echoing Penrose's (1959) concept of 'image' held by manager of future potential growth. This means that firms in the same industry may be making decisions about future activity on the basis of (a) different costs for pursuing the same technical opportunities and (b) a different set of perceived technical opportunities (Teece and Pisano, 1994).

[1] Penrose did not use the term 'organisational capabilities', but her concept of 'productive services' is generally taken to be the original use of the organisational capabilities concept. The term 'organisational

It is quite inappropriate to conceive of firm behaviour in terms of deliberate choice from a broad menu of alternatives that some external observer considers to be "available" opportunities for the organisation. The menu is not broad, but narrow and idiosyncratic; it is built into the firm's routines, and most of the "choosing" is also accomplished automatically by those routines (Nelson and Winter, 1982, p. 134). However, that is not to say that evolutionary economics does not allow for deliberate, reflexive or strategic behaviour by firms. Undoubtedly, there is a great deal of business behaviour that is not, within the ordinary meaning of the term, "routine." Equally clearly, much of the business decision making that is of the highest importance, both from the point of view of the individual firm and from that of society, is nonroutine. High-level business executives do not, in the modern world, spend humdrum days at the office applying the same solutions to the same problems that they were dealing with five years before. We do not intend to imply any denial of these propositions in building our theory of business behaviour on the notion of routine (Nelson and Winter, 1982, p.15).

More recently the literature has begun to emphasise that not all capabilities have the same potential for achieving change. Teece, Pisano and Shuen develop a concept of higherorder capabilities: 'we define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organisation's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions' (Teece et al., 1997, p. 516). The development of concepts such as dynamic capabilities may be seen as a response to criticism that the automaticity implied in Nelson and Winter's concept of routines means that the evolutionary economics theory of the firm is as deterministic as the neoclassical theory of the firm (O'Sullivan, 2000). Other writers have made similar arguments about the limits of models that rely on path-dependence but do not give a role to agent reflexivity and strategic action. These include Sabel (1996) and Tracey et al. (2002). It can also be seen as a valuable expansion of the search routines concept.

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capabilities' is first used in Richardson (1972) (Best and Garnsey, 1999).

Zollo and Winter (2002) have carried out an exploration of the nature and source of dynamic capabilities, which is ‘a significant clarification of the structure of the phenomena’ (ibid., p. 349). They distinguish dynamic capabilities, which they define as ‘systematic methods for modifying operating routines’ (ibid., p. 340), from organisational routines which are ‘geared towards the operational functioning of the firm’ (ibid., p. 340) and are the outcome of ‘incremental improvements…accomplished through the tacit accumulation of experience and sporadic acts of creativity’ (ibid., p. 341). They consider that dynamic capabilities derive from learning mechanisms that ‘go beyond semi-automatic stimulus response processes and tacit accumulation of experience’ (ibid., p. 341). Dynamic capabilities include an element of experiential learning, but are also the outcomes of more deliberative cognitive processes aimed at developing explicit knowledge: ‘dynamic capabilities emerge from the co-evolution of tacit experience accumulation processes with explicit knowledge articulation and codification activities’ (ibid., p. 344). These processes of ‘collective learning’ (ibid., p. 341) ‘achieve an improved level of understanding of the causal mechanisms intervening between the actions required to execute a certain task

and the performance outcomes produced’ (ibid., p. 341). This type of learning can result ‘in adaptive adjustments to the existing sets of routines or in enhanced recognition of the need for more fundamental change’ (ibid., p. 342). While not denying the experiential and cumulative element of dynamic capability, Zollo and Winter’s developed conception of dynamic capabilities captures the strategic actions of deliberate reflection on firm learning and capability. They see, as least partly, that the value of this approach is because ‘the analysis is at a level amenable to strategic action on the part of the firm (while there is relatively little the firm can do to operate on its own cultural features or change its environmental context)’ (ibid, p. 346). What Zollo and Winter call ‘organisational culture,’ where firms ‘place different bets, implicitly or explicitly, on the strategic importance of change in the future’ (ibid, p. 346) I would as identify as the tacit and path-dependent element of dynamic capability, namely ‘image.’ In the case study research presented below I trace the shaping influence of ‘image’ on the adoption of routines for organizational change.

Research Context and Methodology

The context of the research is the recent introduction in Ireland of environmental regulation aimed at stimulating technical change. The introduction of new legislation affords a unique opportunity to study the role of organisational capabilities. Organisational capabilities determine the extent of a firm's fitness with the environment it operates in, and as such underpin growth and survival. The test of organisational capabilities provided by the changed regulatory environment is a strong test for the presence or absence of the requisite capabilities. The research focuses on the experience of one industrial sector, the pharmaceutical manufacturing sector, in making the adjustment to Integrated Pollution Control (IPC) regulations. The IPC licence conditions operate as a uniform test that throws the absence of capability into stark relief, as firms do not have the possibility to compensate for lack of capability with an alternative capability set.[2]

IPC licensing represents a move from single media licensing, which licensed emissions to only one receiving medium (air, water or solid waste), to integrated licensing which considers the environmental impact of a plant's entire activity. 'The main environmental objective of IPC is to prevent or solve pollution problems rather than transferring them from one part of the environment to another' (EPA, 1996a, p. 2). Central to the licensing philosophy is continuous improvement and a shift of emphasis to pollution *prevention* rather than pollution *treatment.* Pollution prevention technology, or cleaner technology, is defined as 'approaches to manufacturing that minimise the generation of harmful waste and maximise the efficiency of energy use and material use' (Christie, 1995, p.31). In cleaner technology, through changes to the manufacturing process, the generation of waste is avoided. The previous approach had been end-of-pipe technology where waste streams emitted from manufacturing processes were treated to reduce or abate the toxicity of discharges to the environment so as to meet emission levels set by regulators. In

[2] In contrast success in the competitive environment can be achieved through different capability sets; a firm that does not have strong product development capabilities may still have a competitive advantage in marketing (Henderson and Cockburn, 1994b). Under these conditions lack of capability is more difficult to identify.

addition to the technical change, regulators now require firms to develop procedures for data collection and setting measurable targets, and environmental management systems; this is intended to support increased cleaner technology take-up in firms. The introduction of IPC licensing required firms to call on technical capabilities for cleaner technology adoption and organisational capabilities for environmental measurement and management; these capabilities were not required for compliance under the previous licensing system. In both aspects, technical and managerial, the regulation represents a radical and challenging departure from the previous regulatory approach.

In this research I have used secondary data made available as part of the IPC regulations and collected qualitative primary data through case study research that has allowed me to explore the more subtle, contingent issues around capability development and deployment. The IPC data allowed for the measurement and analysis of static and dynamic capabilities in the full cohort of 16 pharmaceutical firms licensed in the first phase of the new regulatory regime. That analysis,[3] which identified the strength of dynamic capabilities, provided the information required for case selection. The case study sample was deliberately constructed so as to maximise the opportunities for learning through cross-case comparison (Yin, 1993). Yin suggests that the advantage of multiple case study analysis (over single case) is the increased robustness of the results, which in turn strengthens the credibility of the research and enhances the generalisability of the theoretical propositions developed. 'Cases, like experiments, are generalisable to theoretical propositions and not to populations or universes' (Yin, 1994, p. 10). With these recommendations in mind, the case study research concentrated on firms selected from the top and bottom of the firms as ranked by the full cohort analysis. Cases were chosen to provide examples of both strong and weak/absent dynamic capabilities.

The essence of the evolutionary theory of the firm is that the firm is a repository of knowledge, that this knowledge resides in the organisational capabilities of the firm and

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[3] Further discussion of this analysis, which established the central importance of dynamic capabilities can be found in Hilliard (2002) and Hilliard and Jacobson (2003).

that these organisational capabilities then determine the firm's performance. The earlier research identified dynamic organisational capabilities as being the key factor in managing change. These capabilities are defined in as firm-specific, non-tradable assets, and firms were found to differ with respect to the possession of routines and capabilities for environmental problem-solving and strategic development. It was shown that firms with these dynamic capabilities were more successful in meeting the requirements of the new legislation. Specifically firms with dynamic capability were more likely to have been successful in the development of static managerial capabilities and more likely to have been successful in the uptake of cleaner technologies. A measure of routines for information generation, problem identification and solution and strategic development was developed. It corresponds to the search routines defined by Nelson and Winter (1982): routines for the identification and development of new routines. Here I have assessed each firm for evidence of environmental search routines. Table one outlines the criteria used to assign scores to each firm for dynamic capability.

4	• Well-established routines for data collection and problem identification • Well-established programmes for generating pollution prevention projects • Well-established use of cross-functional continuous improvement teams
3	• Systematic identification of pollution prevention projects • Recent introduction of continuous improvement teams • Integration of problem-solving capability into EMS
2	• Recent and/or limited adoption of routinised data collection or problem-solving • Data collection without use in follow-up problem-solving
1	• No systematic pursuit of pollution prevention • Evidence of environmental management problems due to incomplete information
0	• Absence of pollution prevention projects • Explicit abatement only focus • Long delays in IPC application process due to lack of information

Table 1: Criteria for establishing strength of dynamic capability: routines for the systematic pursuit of continuous environmental improvement

This research explores the origins and evolution of firm-specific capabilities. The finding that dynamic capabilities are central to a firm's ability to adapt to a changed regulatory environment is further explored by examining in detail the organisational processes for problem solving and strategic development. I look at specific examples of firm experiences in generating and implementing new technologies and management techniques, as well as the use of organisational processes for articulating and codifying new organizational concerns and knowledge into routinised behaviour. The choice of case-study firms allows these questions to be explored in the context of examples of both successful and unsuccessful experiences. Table two gives the scores for each case firm.

Pharma C Score = 4	Evidence of Strong Routines • Cross-functional continuous improvement teams • Extensive use of external help • Pushed/advised HQ R&D for cleaner processes
Pharma P Score = 4	Evidence of Strong Routines • Systematic evaluation of environmental impacts as basis for planning environmental management actions e.g. profiles of water/ energy/waste use • Co-operation with corporate HQ and external advice • Policy of rotating staff between Environment and Manufacturing functions • investing in process development to increase learning and knowledge
Pharma K Score = 3	Evidence of Routines • 1989 cross-functional task force to optimize waste water treatment plant • 1992 waste minimisation group for solvent reduction – extensive HQ collaboration/advice • Environmental management plan includes both HQ and plant level continuous improvement efforts; also includes use of teams
Pharma L Score = 1	Limited Evidence of Routines • 1991 waste minimisation committee (meets 4 times p.a.) • 1990 unaware of full extent of air regulations • IPC – could not determine nature of air emissions • Process Development function is strong; tackles environmental problems, but not integrated with EMS or environmental management function • EPA refused permission for abatement solution to emission problem and mandated waste minimisation solution be developed
Pharma G Score = 0	No Evidence of Routines • Review of waste streams for optimal abatement • High level of reporting on abatement performance

Table 2: Evidence of search routines underpinning dynamic capability

In the evolutionary theory of the firm organisational capabilities are the by-products of past learning and experience. One element of this path-dependent view is Penrose's argument that the influence of past learning and experience on the direction of future performance is embodied in the firm's 'image' or perception of its specific future opportunities and environment. In the case study research attention is paid to the different ways in which firms perceive their environmental management performance. An assessment is made of how influential this perception has been in determining the firm's environmental management strategy in specific decisions. Path-dependency is explored by looking at how the current capabilities set has evolved from past activity and experiences, and how this influence persists, despite capabilities also being affected by more explicit strategic processes.

Findings

In the firms with strong and effective routines, the case studies showed that in early, oneoff projects the opportunity was taken to retain the learning and leverage it to become the foundation for later capability. In both Pharma K and Pharma C, early experience with optimisation of wastewater end-of-pipe technology lead to knowledge and organizational processes that supported a programme of cleaner technology initiatives. In Pharma P, an early capability in environmental management was upgraded through involvement in the EMAS pilot scheme. Routines for extensive environmental measurement and subsequent goal setting have allowed the plant to leverage capability into a wide set of environmental projects. This is not the case with the firms with weaker levels of dynamic capability. These plants have had similar early experiences with individual projects (see table three), but have not developed capabilities for environmental management. These firms have not progressed beyond single measurement exercises. Environmental management systems are either unsubstantiated plans for the future, or minimal formal systems that do not drive cleaner technology adoption or continuous environmental improvement.

Strong routines for problem solving and strategic development drive continuous environmental improvement and the pursuit of cleaner technology take-up. Pharma C,

Pharma P and Pharma K have established organisational processes that systematically search for environmental problems and generate programmes of projects to improve pollution prevention. These projects are tackled using established cross-functional, continuous improvement teams, supported by on-going relationships with corporate and external sources of advice and expertise. Pharma P, Pharma K and Pharma C have all established effective organisational patterns for examining environmental performance, determining priorities and developing solutions. Pharma P uses a site profile combined with a management review process to determine areas for development. Pharma C uses a combination of corporate priorities and the site management review to determine goals, and the plant continuous improvement process teams to develop solutions. In Pharma K an inter-departmental task force has evolved to evaluate waste streams and manufacturing processes and develop technical options.

No such formal processes operate in either Pharma G or Pharma L. In Pharma G the only formal assessment of environmental priorities was a one-off project to review waste treatment. Cleaner technology projects, such as source reduction and solvent recycling, appear to be the responsibility of individual departments. In Pharma L pollution prevention is primarily the responsibility of the Process Development function. It takes place as part of ordinary process development work on new processes, and has in the past been undertaken in response to a severe compliance issue. The plant does not have organisational routines whereby management assesses environmental impacts as a basis for planning future environmental management strategy. Pharma G and Pharma L are not only characterised by the absence of the routines described above, but they also demonstrate evidence that this lack of capability has adversely affected their relationship with the EPA, ultimately leading to reduced flexibility of action. Problems such as incorrect interpretation of regulations, refusal of approval for proposed environmental projects, mandated changes to organisational processes, unannounced visits by EPA auditors, and ultimately prosecution are all examples of how, in these plants, weak environmental management capability acts as a costly constraint on plant management.

The firms with strong routines did not necessarily begin their environmental management

development earlier than the weaker firms (see table three). In none of the firms did significant initiatives predate 1989, and most firms only began to implement changes at about the time that the industry would have become aware of the proposed IPC legislation. The success of regulatory compliance among some firms does not appear to be explained by recourse to any quantitative factors. The explanation lies rather in the qualitatively different experiences or evolutionary paths of these firms. Despite starting from a similar position to the other firms in the cohort, these firms made more of the opportunities presented.

Penrose (1959) suggested that what an organisation was able to do in the future was shaped by experience gained from past growth. But further than this she argued that past experience shaped managers' image of the opportunities open to the firm. Teece et al. describe this as 'a firm's past experience conditions the alternatives management is able to perceive' (1997, p. 524). Hodgson (1996) draws the distinction between information and knowledge; information becomes knowledge only after interpretation, and the same information may not provoke the same knowledge, the difference being the interpretation performed by the firm's cognitive framework or perception, or 'knowledge is processed information' (Fransman, 1994, p. 717). In the five case firms it was clear that, in response to the same external regulatory demands, they each had a different perception and interpretation of what was required to develop their environmental performance to the necessary standard. In Pharma P, the perception is that the plant benefits from taking up opportunities to maximise and exploit learning and also that environmental excellence benefits the plant.

In Pharma C the perception is that an integrated, cross-functional approach to continuous improvement is key to maintaining the plant's competitiveness within the corporation; environmental management, as a fully integrated site function, has a role to play in achieving increased efficiency through cleaner technologies. Pharma K's strategy is driven by the belief that a high level of environmental control is important to the plant's ongoing survival, and that increasing control is best achieved through pollution prevention, not abatement. In the successful firms their 'image' was congruent with the

development of cleaner technology and processes for continuous improvement and included the integration of environmental management with overall strategic development.

Pharma G's view is that 'legislation only requires control'. They point to their substantial investment in abatement technology, allowing them to achieve emissions levels far below the levels set in their licence, as proof of their commitment to environmental excellence. At plant and corporate level pollution prevention is interpreted as being emissions reduction achieved through abatement. The environmental manager has no formal involvement in pollution prevention. Pharma L similarly perceives a limited role for the environmental management function in driving forward cleaner technology projects. Environmental improvement is characterised by the company as a function of equipment and investment, rather than the use of experience or capability. Again, the plant points to its large investment in abatement technology as an example of commitment to environmental improvement. In both Pharma G and Pharma L the perception is that opportunities for future cleaner technology projects are limited; the reasons given are that the projects that have been carried out are seen as sufficient and as having exhausted all opportunities. In both plants the function of environmental management is to ensure compliance with minimal disruption to the core activities of the firm.

Pharma P, Pharma K and Pharma C routinely put together projects that relied on interdepartmental teams. This has been identified in the organisational capabilities literature as an important competence that allows for leveraging knowledge from different areas.Henderson (1994) defines integrative capability as the ability to integrate fragmented knowledge across boundaries within a firm; this capability shapes the control of information within the firm and the structuring of 'organisational attention' (p. 608). Within the cleaner technology literature it has been identified as being important for developing cleaner technology solutions, which are not restricted to one area and discipline (such as end-of-pipe, engineering solutions for waste treatment) but cover the whole production process and a multiplicity of approaches (Christie, 1995; Jackson, 1993). It also serves to build environmental awareness and capability within other

functions, such as manufacturing and process development. In Pharma G and Pharma L there is limited formal integration; the perception is that environmental management is a support function and a priority is not to disrupt the main business of production. Cleaner technology projects are carried out, but without the involvement of environmental management. These projects are often primarily undertaken for efficiency reasons, with environmental benefits a side effect rather than a driver.

Pharma P, Pharma C and Pharma K all made effective use of knowledge accessed from external sources. Cohen and Levinthal (1990) argue that this is an absorptive capacity, the ability to 'recognise the value of new information, assimilate it and apply it to commercial ends' (ibid., p. 128) and is an element of a firm's organisational capabilities set. It is 'largely a function of the level of prior related knowledge' and is developed from the intensity and accumulation of past learning. Pharma P and Pharma C have both employed the Clean Technology Centre to help with the development of projects, and in both cases the knowledge has been successfully integrated and used to upgrade the firm's own capabilities. Pharma K has worked with the corporate environmental laboratory to increase its understanding of solvent recycling. Routines for the development of solvent recycling in new products have been successfully transferred from the corporate function and replicated at the plant. Pharma G and Pharma L considered that the plant's own, internal resources were better than any external advice; in both firms there were examples of external advice that had been sought, but ultimately not implemented.

In conclusion, dynamic capability in these case companies involves both tacit and explicit elements. The firms with effective capability are characterised by the presence of routinised processes that have been put in place as the result of strategic action. These processes are for planning change, for reflecting on past performance, for embedding and routinising learning, and for leveraging knowledge. However, there is a significant tacit, experiential and path-dependent element to environmental management strategy in these firms. Why these firms made decisions to pursue effective strategies, and other firms made equally deliberate decisions to follow different strategies seems to be in large part shaped by each firm's perception of the opportunity set it faces. This accords with the

description of dynamic capability put forward by Zollo and Winter: 'dynamic capabilities emerge from the co-evolution of tacit experience accumulation processes with explicit knowledge articulation and codification activities' (2002, p. 344).

Case firms with evidence of strong routines		
Pharma P	1989	Award for environmental management
	1992	Approached to join EU EMAS pilot scheme
	1994	Undertook first major waste minimisation project
	1996	Undertook utilities reduction project
		Established waste minimisation group
	1997	Achieved EMAS accreditation
Pharma C	1988	Introduced first corporate environmental strategy
		Set goal of chlorinated solvent elimination in 10 years
	1989	Appointed environmental manager
	1991	Established separate environmental function
		Undertook major solvent reduction project
		Introduced use of environmental measures
	1992	First annual corporate environmental report
	1993	Participated in corporate waste minimisation project
	1997	Achieved ISO14001 accreditation
Pharma K	1989	Undertook major waste evaluation project
	1991	Issued corporate environmental policy
		Issued corporate guidelines on waste minimisation
	1992	Investigated solvent recycling
		Established waste minimisation working group
	1996	3 year plan to pilot EMS corporate standard
Case firms with limited or no evidence of routines		
Pharma G	1990	Set corporate goal of 90% emissions reduction through equipment upgrading
		Introduced environmental management programme - equipment upgrading and environmental training
		Part of corporate emissions reporting system
	1994	Undertook waste stream evaluation project
Pharma L	1991	Established R&D waste minimisation committee
	1994	Appointed an environmental officer
	1997	Achieved ISO14001 accreditation

Table 3: Key dates in environmental management development of firms

Conclusion

It can be seen from the presentation of the cases that firms with strong dynamic capabilities had implemented the sort of deliberate learning strategies identified by Zollo and Winter as being aimed at improved understanding of the causal links between actions and performance, through knowledge articulation and codification. In this way capability can be seen to enable strategic behaviour, rather than purely automatic or deterministic responses, as firms were able to identify and accumulate capability in new areas.

Zollo and Winter's (2002) extension of this work concentrates on the intentional elements of dynamic capability, that is, knowledge articulation and codification, while acknowledging that the tacit is also important. A little explored question from the literature relates to the absence of capability. If the definition of capability is that it is the accumulation of learning and experience, this implies that potentially all the firm's past experiences will become embedded as routines and capability. This suggests that all firms will have capabilities, the difference being that not all firms will have the capabilities that provide for success in a given environment. The evidence of this thesis is not that firms have good or bad environmental capabilities, but that some firms have capabilities, where others appear to have limited or no capabilities for environmental management. The research using capability indicators showed that the difference lay with the presence or absence of routines for identifying, developing, leveraging and embedding new knowledge, analogous to the processes identified by Zollo and Winter (2001). The role of reflexive action may explain why not all experience gets translated into capability and some firms may not possess any capability in a given area.

It can however also be seen that there is a significant cumulative and experiential influence shaping whether or not a firm pursues such deliberate learning mechanisms relating to differences between firms in terms of the way environmental management responsibilities and opportunities were framed. Where Zollo and Winter point to a 'major research thrust that seems to be emerging, the effort to expand our understanding of how cognitive activity of a deliberate kind shapes organizational learning, knowledge and action' (2002, p. 350) I would argue that consideration of deliberate learning mechanisms

needs to be balanced by a similarly detailed exploration of the influence on learning of persistent and tacit firm perceptions.

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