'KNOWLEDGE MANAGEMENT PRACTICES' AND PATH-DEPENDENCY IN INNOVATION*

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1. INTRODUCTION

An increasing number of researchers and commentators have recently been turning their attention to 'knowledge management'[1], and particularly the role of knowledge management in innovation[2]. It seems that there are two major underlying influences which are at work in these discussions, and that they have both complementary and contradictory features.

The first of these influences can be seen as 'internal' to innovation research and it is the literature which synthesises the received findings of 'innovation studies' into an evolutionary economics perspective on technical change. The central feature of this work for our purposes is its weaving together of the observed path dependency of innovation, with the firm-specificity of the routines which generate innovation. For example, Metcalfe & de Liso[3] elaborate the idea that a business unit will have a specific 'normal design configuration', a shared mental framework of fundamental design concepts relating to specific technologies, providing the 'operational route' to specific artefacts. Thus the perspective in this literature links knowledge to innovation by focusing on firm-specific routines which stabilise certain bodies of knowledge, embed them in the shared understandings within the firm, and provide templates for deploying that knowledge to produce innovations which have a distinctive organisational 'signature'.

The second underlying influence in the 'knowledge management' literature has arisen at the interface of innovation research and management research. It derives from the perceived increase in importance of knowledge as a factor of production and as a driving force in broader changes in the nature of contemporary economies, and in the enterprises which operate in those economies. One of the key reference points in the emergence of a new focus on 'knowledge management' in enterprises is the work of Nonaka[4]. Arising originally from empirical studies of new product development in Japanese firms, Nonaka has developed a model of the various ways in which organisations create knowledge and has suggested a style of management and an organisational structure for best managing the knowledge creation process, namely the 'hypertext organisation'. Central to the model (as indeed to much other work on knowledge management) is Michael Polanyi's distinction between tacit and explicit knowledge. Nonaka argues that tacit and explicit knowledge can be converted from one to the other, and his main focus is managing the interactions between the four 'modes of knowledge conversion'. Another major contributor is Dorothy Leonard-Barton[5] who bases her discussion

more firmly on the 'core competence' strategy literature and has a focus on what she calls "the *whole system* of knowledge management" (*ibid*, pp 271-2, original emphasis), which is seen to be an integral element of competitive advantage, or 'core technological capability'. Her specific interest is in the 'key knowledge-building' activities shared problem solving, implementing and integrating new technical processes and tools, experimenting and prototyping, and importing and absorbing technological and market knowledge.

In many ways, these two perspectives - the evolutionary economics perspective and the 'knowledge-centred-model of the enterprise' - are compatible with each other. At the very least it can be argued that they have considerable potential to enrich and illuminate each other. However, in one crucial respect they present different pictures of the nature of, and possibilities for, 'knowledge **management**' in the firm. This difference concerns the degree to which a firm is intrinsically limited in the degree to which it can modify the content and scope of its knowledge base. Simplifying somewhat, the Nonaka/Leonard-Barton perspective emphasises the potential open-ness of the firm to the acquisition of external knowledge and the possibility for the firm to increase its potential to create radically new knowledge. In a sense it presents a relatively increased possibility of 'breaking free' of path dependency. In contrast the evolutionary economics perspective emphasises the way in which the knowledge base of a business unit[6] and its routines of operation **reinforce** path dependency and limit the rate of integration of external knowledge or production of radically new knowledge. To put the problem in the language of evolutionary economics, the two perspectives pull in different directions on the question of the degree of variety generation which is possible **within the firm**. It is clear that variety generation within the firm is **constrained** variety generation - but the question which is posed in this discussion is the extent to which the firm can **modify** those constraints on its variety generation[7].

This paper proposes an approach to understanding and researching knowledge management which is designed to explore this problem in more detail. The central feature of the approach is a theoretical and empirical focus on knowledge management **practices**[8] in the firm, which is in contrast to the focus, characteristic of a great deal of the current literature in this field, on categorising different **types**[9] of knowledge. In particular, it will be argued that it is vital to look not only at the effects of existing knowledge management practices on innovation within

the firm, but also to account for the creation and maintenance of new knowledge management practices.

In section 2 of the paper, the case for a focus on knowledge management practices is elaborated. In section 3 a taxonomy of knowledge management practices is presented, with some illustrative examples. In section 4, the paper returns to the question of variety generation within the firm and considers how knowledge management practices create both the possibility of variety generation and the limits around that possibility.

2. THE CASE FOR STUDYING KNOWLEDGE MANAGEMENT PRACTICES

One starting point for the study of the role of knowledge in innovation at firm level is to focus on the various forms which knowledge can take and the modalities in which it plays a role in innovation. The pedigree for this approach goes back to Polanyi, as has already been noted. But, as Faulkner[10] demonstrates, a variety of innovation studies have for many years developed categorisations of the knowledge used in innovation which go beyond a simple distinction between tacit and explicit. For instance, Fleck & Tierney[11] distinguish seven knowledge types, ranging from 'metaknowledge', through 'formal' and 'informal' knowledge, to 'instrumentalities', whilst Vincenti[12] identified six rather different categories. Drawing together these and other categorisations, Faulkner[13] builds a 'composite typology' of 15 types, grouped according to the 'object' of the knowledge. Finally, the types can additionally be grouped along another axis concerning five distinct sets of 'characteristics' of knowledge:- tacit versus articulated; complex versus simple; local versus universal; specific versus general, and understanding/information/skill.

This approach can clearly be fruitful if the research objective is to construct plausible accounts of the development of specific innovations and technologies within one firm or a network of firms. Different episodes, individuals, and arguments can be categorised in terms of these types of knowledge. However, it is less appropriate as a starting point if the objective is to move toward a more generalised account of the role of knowledge in constrained variety generation at firm level.

For this purpose it is more appropriate to shift the focus away from the **types** of knowledge and towards the **mechanisms** through which knowledge affects innovation possibilities.

Examples of the broad classes of mechanisms which might be relevant include **accumulation mechanisms** which govern the content and location of the 'stocks of knowledge' in the firm; the **interface mechanisms** which govern the balance between, for example, internal and external sources of knowledge; and **deployment mechanisms** which govern the ways in which the stocks of knowledge are brought to bear within decision-making. Mechanisms such as these are important in defining the collective knowledge - both formal and tacit - in an organisation, which makes one organisation's behaviour different, and **consistently different**, from another organisation. We propose that the most fruitful way to investigate these mechanisms which link knowledge to innovation is to first re-examine the notion of path-dependency in innovation - since it is the idea of path-dependency which is at the heart of the contemporary understanding that innovation is a process which is intrinsically firm-specific.

The notion of path-dependency is centred on the idea of positive returns[14]. Doing things in a particular way, whether it be designing, manufacturing or marketing a product, yields effects which pre-dispose the organisation to do (at least some) things in the same way the next time round[15]. If we consider the way the idea of path dependency has been developed in studies of innovation and in evolutionary economics in recent times, it becomes plain that this manifestation of path dependency is potentially 'located' in three different domains within the firm. The first domain, ‘technology-as-hardware’, comprises the specific technological artefacts such as products, machinery, equipment, software etc. These items bear the impression of previous choices and chance events, and they shape future possibilities for the development of further artefacts.

The second domain in which path dependency may be located is the 'knowledge base' of the firm. This knowledge base can be variously interpreted. For Metcalfe and de Liso[16] the knowledge base is quite closely connected to the technologies and customers currently familiar to the firm, and consists of the 'shared mental framework of fundamental design concepts' mentioned above. However, for some writers in the evolutionary economics school there are more aggregated levels of 'knowledge base' in the firm which shape action. Hodgson[17] for example, argues that 'corporate culture' provides an explanation of the 'existence and relative efficiencies' of firms, an explanation that is superior to the transaction-costs approach to forms of co-ordination. Commencing with a discussion of the ways in which firms cope with 'radical uncertainty', and hence are required to ensure that learning

takes place, it is argued that maintaining the 'competencies' of groups and individuals requires that the firm has a capacity to 'mould the individual perceptions, preferences, abilities and actions of its personnel'. This capacity is operated partly through the ability of the firm to generate trust and loyalty, but more importantly through the 'transmission' of a corporate culture. This culture consists of 'shared information ... practices and habits of thought'.

Path-dependency may therefore be seen as being located in the 'knowledge base' of the firm as narrowly defined by the specific technologies and markets of which it has experience, or more broadly defined as the culture of the organisation, which includes but transcends the more narrow definition.

The third potential domain in which path dependency might be located is the collection of **routines** which are carried out in the firm in order for it to conduct its regular business. Particularly important for our purposes of course, are those routines which are related to innovation. These would include routines which **deploy** the existing knowledge base of the firm in order to make sense of particular problems in the area of product and process development. These would include routines which aim to characterise customer requirements; to identify feasible technical solutions; to establish projects and work plans to implement those solutions; and so on. These routines, by their sheer **repetition**, serve to reinforce the distinctiveness and legitimacy of **both** of the other domains mentioned namely the knowledge base and the previously accumulated technology and hardware. However, these routines would also be capable of exposing perceived limitations and weaknesses in those areas, and thus open up (path dependent) avenues through which those weaknesses are addressed.

From this discussion it seems plain that the phenomenon of path-dependency may indeed be located in all three domains: in the ‘technology-as-hardware’, in the knowledge base, and in the routines of the firm. This follows from the way in which the three domains are bound up with and depend on each other. The knowledge base structures the routines, which in turn deploy knowledge to create the technology, which in turn underpins the knowledge, and so on. Where then should the focus of research be, if our aim is to explore the claimed potential for active 'knowledge management' to **modify** the limits on innovation posed by path dependency? Should we focus on the technology, on the knowledge, or on the routines?

If we focus on the technology-as-hardware, we are restricted to looking at something which only reveals the traces of path-dependency once it has become an 'output' of the firm[18]. This may be valuable in the development of a sociology of technology, but is too limited as an approach to understanding knowledge management in real time in companies. If we focus on the knowledge base as a site of path-dependency, we are faced with the very difficult task of identifying those aspects of a company's knowledge base which confer firm-specificity on its activity. These are by definition often the most tacit dimensions of the knowledge and therefore the most difficult to access. Furthermore such an approach encounters the many difficulties[19] of developing and applying metrics for knowledge which can be applied in empirical studies. However, if we focus on the **routines** which are involved directly in the development and application of the knowledge base, we have a more tractable situation. We can list some of the advantages of treating routines as the focus of analysis.

* The routines can be empirically observed as practical activities, such as the conceptual structuring and archiving of a technical document; or selecting external sources of knowledge to access and to disseminate internally.

* The routines will have certain common features which 'transfer' from one firm setting to another, but which are also capable of being given a greater or lesser degree of importance by firms, or are capable of being implemented in a different way.

* The routines are (potentially) topics which are the subject of debate and change within a company, as it reflects on its performance and makes changes. This also makes them more visible to the researcher, and makes changes open to discussion in terms of reasons and rationales for change.

These points will be developed further below. However, to recap the argument so far, we suggest that the phenomenon of 'knowledge management' in the specific field of innovation lends itself to a research approach which focuses on the interplay of knowledge management and the generation and maintenance of path-dependency in the firm. In order to uncover this interplay, the most fruitful activities to examine are the routines which connect knowledge

and innovation. We propose that there are specific routines which we call 'knowledge management practices' (KMPs), which are particularly important in shaping the knowledge base of the firm and making it available in the in the innovation process. A suggested taxonomy of KMPs is presented in the next section of the paper[20].

3. TYPES OF KNOWLEDGE MANAGEMENT PRACTICE

In this section we first present a framework for understanding KMPs which is designed to guide empirical research. Section 3.1 first presents the framework in terms of the **components of a KMP.** In section 3.2 we present a list of KMPs which are grouped according to their principal **functions** with respect to innovation. A final category of KMPs is defined in terms of the enabling role being played by information technology applications which permit KMPs to be significantly modified, or indeed trigger the creation of new KMPs. In each case the KMPs are briefly illustrated with examples drawn from company case-studies which are part of an ongoing research programme[21].

3.1 The Components of Knowledge Management Practices

Knowledge management practices take a variety of forms, and this creates a need for a flexible approach to describing and classifying them. The approach needs to be able to cope with practices which are both formal and informal; paper based and electronic; people-driven or system driven; wholly knowledge centred or only partially knowledge centred, and so on. We propose a model of KMPs which has four components. These are as follows:

1. The character of the practice in terms of what **process** the knowledge is subjected to.
2. The knowledge **domains** or topics addressed by the practice
3. The **format** of the knowledge management practice.
4. The part of the organisation's **performance** which is most impacted by the KMP.

In some circumstances it is also possible to identify the principal actor(s) involved in a KMP. However, we do not include the actor as a necessary part of the KMP itself, since in some cases agency is unclear or contested[22].

Thus a typical KMP may be carried out by an actor, but it will certainly relate to a specific knowledge domain. It will perform some action on the knowledge in a particular way, be conducted within a specific format, and have particular effects on the organisation. To give a specific example: the **manager of a pilot plant** (the actor) for the manufacture of a polymer may prepare a **technical report which captures operating data** (the process) on the efficiency of a **new catalyst** (the domain). The report may be rapidly available through **Lotus Notes** (the format) to R&D personnel working on optimising the catalyst and may therefore improve the **efficiency of the R&D process** (the performance parameter).

We can now expand the description of each of these four elements of a KMP in turn.

The Processing Characteristics of the KMP

It has traditionally been assumed that there are three broad characteristics to knowledge processing:- **generation, transfer and utilisation**. However, this is a somewhat narrow approach more appropriate to information than knowledge. From reviews of the literature on types of knowledge (Faulkner op cit) and from empirical studies we propose the following additional characteristics:- **identification** of knowledge that may be useful; **capture** or retrieval of knowledge; **altering the format** (for instance; **codifying** knowledge by transferring it onto paper or onto IT systems); **validation** of knowledge (for instance, through discussions with peers); **contextualising** and re-contextualising (for instance, looking for common aspects between the original context of the knowledge, and the intended context); and achieving **'closure'** (for instance, the processes of agreeing common definitions). Thus the essential feature of a KMP can range from relatively 'routine' activities such as recording data; through to more judgement-based and potentially contestable activities involving selection and contextualisation of knowledge.

Domain

There is often a specific knowledge focus for KMPs, involving a delimited area of knowledge targeted by that practice. Such areas may include:- highly specified areas of scientific and/or technical knowledge and related to particular journals, conferences, or professional associations; knowledge of particular products or processes; knowledge of particular markets and customer bases; knowledge of particular features of the organisation; and knowledge of

projects, project processes and project management. Thus the broad categories of domain are **Technical** (both internal and external to the firm), **Market**, and **Organisational Procedures.**

There may also be a more general focus for a KMP, which may include:- knowledge that may arise unpredictably, for instance through synergy or co-location; knowledge that is needed by new or younger personnel from time to time, for example during personnel induction and continuing mentoring practices; and knowledge that others may find useful, for instance the practice of publishing material on internal Web pages on an 'intranet'.

The Format

As already suggested above, particular KMPs may vary between 'formal' and 'informal'; from a highly specified and standardised job-role of specific individuals, through to a general expectation that people will carry out the practice (for instance, passing on useful knowledge). Any KMP may also be expected to take place at specific times or locations, for instance during particular meetings, or during the 'demand analysis' phase of projects, or within the space where project teams are clustered together; it may be directed at enabling ad-hoc, temporary or rapid arrangements, for instance by establishing links and contacts between people with shared expertise or interests. Alternatively a particular KMP may be set up within MIS or ICT systems, and hence be specified and constrained to varying degrees, so that for instance email discussion lists may be seen to be far less formal than a shared database or groupware system with strictly delimited field attributes.

This question of the format of KMPs is of particular topical concern at present. The rapid diffusion and refinement of IT techniques for the archiving and distribution of knowledge is now penetrating R&D functions in companies. Formal 'information management' procedures and personnel who have up to now been concerned with other areas of company activity are now turning their attention to R&D and innovation as an area where they can make a significant contribution. Furthermore the significant growth of multi-site R&D and electronically-enabled virtual R&D project teams is providing a fruitful recruiting ground for their ideas.

The Organisational Performance Variable(s) Impacted by the KMP

This is the most problematic one of the four elements to specify clearly. The reason for this is the well-known difficulty surrounding the creation of relevant and accepted measures for the efficiency and effectiveness of R&D and innovation. However, there are some 'micro-measures' of the performance of certain elements of the R&D function which provide a point of reference. For example, clever and prompt interpretation of competitors' patents and patent applications, and the communication of that knowledge to an R&D team, can identify the degree of **'design freedom'** available to that team and result in a better targeting of their effort.[23] In most circumstances it is at least possible to identify an **intended** performance effect of a KMP, even if in practice it is often difficult to measure that effect.

3.2 The Functions of Knowledge Management Practices.

In this section we briefly describe some of the characteristics of the main KMPs that might be encountered within a firm, which we divide into five major functional groups.

Group A: KMPS Located in the Formal R&D Management Process

These are KMPs which are found to varying degrees in all R&D and innovation environments, and which often have other primary purposes. The main examples are:

* Writing technical reports on outputs of R&D projects. This is a procedure often viewed as routine. In fact however, it depends fundamentally on the use of concepts, language and cross-referencing processes which are deeply influenced by the existing knowledge base of the firm, and which reinforce that knowledge base. Furthermore the relevance of technical reports to knowledge management is being transformed in some companies by the placing of the reports in electronic archives and making them searchable by other R&D or marketing personnel (see Group E below).

* Periodic reviews of projects, departments, and other relevant organisational sub-units in an R&D lab. These procedures generate documents and shared tacit knowledge which play an important role in contextualising knowledge and creating shared categories for identifying 'that which is important'. They

also play a role in forming a formal or informal inventory of skills and capabilities in the R&D function.

* Physical clustering of R&D projects in cognate technological areas has a profound effect both on the generation and sharing of technical and market knowledge, and on the demand for relevant knowledge to be supplied to such groups by other internal services such as the library/information service department, and the IPR department.

* Secondment of personnel across the R&D/Marketing interface; as well as between product or technical teams has an important effect on knowledge transmission and on identification of new types of knowledge deemed to be relevant to specific pieces of R&D work.

These KMPs in Group A are at the heart of the key 'knowledge circuits' in R&D. They grow directly out of the performance of the R&D work itself, and are typically embodied in the R&D scientists and their formal and informal communication patterns within and beyond the lab. The importance of such knowledge-centred activities has been recognised for many years, going back to the work of Allen[24] on gatekeepers. Some aspects of this set of KMPs have not changed fundamentally since then. Other aspects are changing rapidly as a result of the greater formality of R&D planning processes, and the opportunities to use information technology to change the range of options for the storage and dissemination of documents and data.

Group B: KMPs for Managing Intellectual Property Positions

There are a number of KMPs in the field of intellectual property rights which reflect the fact that in-house IPR experts in R&D labs are becoming more pro-active. Instead of principally providing a service to formulate patent applications and maintain patents, it is now more common to find them actively distributing information about competitors' patent activity to R&D teams, with commentary on its implications for the strategic direction and detail of the company's own R&D. In some cases this activity is conducted jointly with library staff to provide an electronically delivered 'Patent Watch' service available to the desktop of individual scientists.

A second major KMP in this group is the early involvement of IPR staff with R&D teams to formulate the IPR dimensions of emergent instances of novel technology. The distinguishing feature of this practice is that IPR expertise is being used to influence the direction of R&D technical activity in mid-project.

Group C: KMPs for 'Mapping' Knowledge Relationships

R&D organisations are typically organised around project teams and around departments with specific technical expertise. Often these two reference points for organisation form the two sides of the matrix in a matrix management structure. However, even with this type of structure, emergent nodes of technical expertise which develop around particular categories of problem can often be relatively 'invisible' and not formally located within one of the strong cells in the matrix. Similarly, emergent bodies of knowledge and experience about customers, competitors and market segments can arise in parts of the R&D organisation, but not be formally 'owned' by anyone in the management system. These 'orphan' fragments of knowledge can be even more numerous and difficult to locate if there are multiple R&D centres in the firm, and multiple networks of contacts with business units, and with their customers. In many companies a group of KMPs have emerged which are concerned with mapping these fields of knowledge and person-embodied skill, and making the resulting maps available to managers to provide new perspectives on the company's innovation activities. These mapping KMPs can be subdivided into those which target internal technologies, external technologies, customers and market segments, and inter-company relationships. These are now discussed in turn.

C1: Internal Technology Maps

There has been an increase in the development of specific KMPs designed to **identify and map** the range of specific domains of technology-centred knowledge in the R&D centres, and to similarly identify and map the parallel categories of 'market-centred' knowledge. In some cases this activity may be organised as a formal 'technology audit'. In other cases it may be much more ad hoc, and dependent on particular groups or individuals taking an initiative from the bottom up. The salient point in each case is that a pockets of knowledge and skill which are not project or product specific, by virtue of being named, take on a more solid existence.

It should be stressed that some of the items that find their way onto these maps are obvious and not surprising to anyone in the centre, but that others are surprising, and are then the cause of discussion and debate about whether 'anything should be done' about these pieces of knowledge in terms of their formal recognition as new parts of the lab structure, or in terms of the more active dissemination of the knowledge to others in the business who might make use of it.

C2: External Technology Maps

A major distinction within this group of KMPs is that between the mapping of **internal** knowledge within the firm, and the mapping of **external** knowledge in other firms, in research agencies, in universities, in the public literature, patents and so on. The balance between these two types of mapping depends on firm-specific factors such as history and innovation posture. It also reflects the view of the firm regarding its degree of self reliance or dependence on external technology. Where both internal and external mapping are highly developed this can result in a third sub-set of mapping KMPs which explore and establish **connections** between the firms internal technologies and its external technical environment. This is clearly one of the most important categories of KMP in terms of the issue of variety generation and the modification of path dependence.

These mapping initiatives are being taken by diverse groups in the R&D centres, but library and information science professionals are a strong promoter of the ideas. These groups have the special skills and technologies to monitor publications, grants, conferences, patents etc, and to categorise them into relevant categories for presentation to research teams. But such activity is transformed from the merely administrative to the strategic if the categories chosen and the audiences addressed are linked directly into the fine-grained technological ideas which underpin actual R&D projects.

Examples of this trend are the increasing use of proactive dissemination of topic-centred news-sheets (often electronically delivered) which are placing company-specific items of technical and market intelligence in front of R&D scientists. The more radical versions of this development involve the formal use of company 'intranets' for this purpose, as well as judicious and secure use of internet access for external searching. Some companies now cite

the issue of 'information failures' amongst R&D scientists as part of the justification for the expenditure on an 'intranet'.

Moreover these mapping KMPs are not entirely conducted in virtual space. One of the frequent consequences of the mapping processes is that people in different parts of the organisation find that they have a common interest in a particular technology or application-centred topic, and form (either officially or unofficially) a new 'interest group' which can sometimes congeal into a formal new skill centre with a budget and a brief to develop the skill.

C3: Market Mapping

Mapping KMPs are not restricted to working with technical knowledge. The work of R&D staff in centres with a strong product development orientation is profoundly intertwined with assessment of customers and their reactions to the functionality of products and services, and to the products of competitors. This is done by marketing personnel in product development teams, by technical marketing staff in follow-up field work, and often by R&D staff directly in customer interactions. Consequently it is possible to find significant mapping activities focused on markets, market segments, customer behaviour, future customer requirements etc. This is not simply the 'market research' of the conventional marketing department, (although that is relevant here as well), but is something more organically embedded in the 'innovation community' in the firm. This is centred on the R&D staff, but extends beyond them to a variety of more 'customer-involved' groups. These KMPs which generate and organise market knowledge, if articulated with the internal and external technology mapping KMPs, are a central part of the variety-generating potential of the firm. It is these routines especially, and the modification of these routines, which hold the key to the possibility of partially 'relaxing' the constraints of path dependence in innovation.

C4: Mapping Inter-Company relationships

In industrial sectors such as biotechnology there are many complex inter-company relationships centred on technology transfer, licensing, joint R&D and so on. Companies in these circumstances find it valuable to have separate mapping activities which track these alliances and relationships, often strongly linked in to their mapping of external technologies. The results of the relationship mapping can sometimes reveal the development of 'patent

roadblocks' which make certain research directions less fruitful; they can also help in predicting changes in the strategic posture of competitors, and can assist in the evaluation of new options for alliances.

These four categories of mapping KMP (C1 - C4) are a major aspect of emerging new knowledge management practice, with their own distinctive skills and techniques.

Group D: KMPs For Serial Transfer of Project Experience

In some companies R&D activity centres around a small number of very large projects, which last a long time, and which are very context specific. Examples would be the design and building of a chemical plant in another country; or the design and building of a large civil engineering project such as an airport terminal. For these companies, one of the difficulties in 'Knowledge management' is that teams of people are assembled to do the work, and they acquire a great deal of experience and skill which appears to very specific to 'getting that project done' but which in fact conceals some potentially generic and transferable lessons. But the culture of such R&D work is that the completion of the hardware is the driving force, and after that is complete, the teams are broken up and there is low motivation to reflect on, and document the transferable experience and re-use it in future projects. This leads to frequent instances of re-invented wheels.

Such circumstance can give rise to a cluster of KMPs which constitute a quite highly developed solution to this problem. For example, in one particular design and construction company, a large team of R&D personnel do nothing else but interrogate, contextualise, present and re-present 'project experience' in ways which try to 'fix' it as the accumulated current best practice of the company. Thus on the question of, for example, how you specify appropriate acoustic insulation levels for offices in particular geographic markets, and how you procure the appropriate (and sometimes quite varying) building materials in those markets to reach those acoustic levels, a set of guidelines and procedures will be formulated and made available to all technical personnel in the field.

This cluster of KMPs is currently largely paper based in the form of manuals which project staff carry around with them. Interestingly, this is a case where although the KMP is highly evolved, it is not being driven by IT enabling processes (as some other KMPs are) because

the IT is still a less convenient format than paper for the very mobile character of the project staff who use the knowledge.

Group E: KMPs Contingent on Information Technology Applications

As has already been mentioned, information technology applications can be a significant enabler of the emergence of new KMPs. Examples are the electronic archiving of technical documents which emerge from R&D work (Group A above); electronic 'Patent Watch' bulletins(Group B above), and Intranet approaches to the facilitation of clusters of R&D expertise making their skills available to previously unknown collaborators elsewhere in the corporate structure (Group C above). In the case of Group D KMPs (serial project experience transfer), it has already been noted that in the context of civil engineering, this is not necessarily dominated by electronic media, although they do have some role. In the context of the building of chemical plants however, the role of information technology based modes of knowledge capture appears to be somewhat greater.

There is however a distinction to be made between those cases where IT **supports** a KMP which has a strong independent existence, and those cases where IT provides the trigger to create or change a KMP. There is no doubt that email availability has facilitated the emergence of new R&D virtual clusters of personnel, and that some of this activity is therefore 'bottom up' activity enabled by the unintentional consequences of email availability. It is also our observation that the availability of groupware packages such as Lotus Notes has stimulated experiments in new ways of sharing knowledge in project teams that might not otherwise have been attempted. Similarly, the rapidly diffusing experience of individuals using the world-wide-web has raised expectations and interest concerning the potential of its corporate equivalent: the 'intranet'.

In addition to these changes in the availability of IT, we can also note the fact that R&D centres are now attracting the attention of information management specialists from the corporate centre, who have already cut their teeth on information systems to support operations management, finance, and marketing functions; and are now asking the question 'what is the strategic role of IT in R&D?'. This leads to the emergence of champions and of the relevant expertise to actually implement such projects as electronic archives of technical data, intranets, and the like.

Relationships Between KMPs

In section 3 we have developed a framework for categorising knowledge management practices, based around four dimensions or attributes of KMPs. These dimensions have not been predicated on any particular understanding of the nature of knowledge or the desirability and techniques for knowledge management. Instead we have developed a perspective that views KMPs as one instance of practices in general, and hence described them in terms of their objectives (what is 'done' to knowledge, and what is the 'domain' of that knowledge), and in terms of the format or degree of structuring of the KMPs. We have then used these dimensions to describe and to classify some of the most common KMPs to be found in R&D and innovative activities. Whilst many of these have been established for some time and are clearly embedded as routine activities within R&D, others are emerging from within established sub-departments of R&D or across organisational boundaries, and they are either instigated at a senior level or appearing as bottom-up initiatives.

Despite the preliminary state of this taxonomy, it is nonetheless interesting to note that there are some broad patterns visible in the interactions of the KMPs in any given R&D unit. The **knowledge base** of a company was identified in section 2 of the paper as important to the understanding of path-dependent innovation within the evolutionary perspective. We suggest that knowledge management practices drawn from all 5 of the categories described above can be seen to contribute in three distinct ways to that knowledge base.

Firstly, the KMPs constitute and enable discussion of an evolving 'stock' of knowledge about technologies which the company can deploy, and about the significance of those technologies. Furthermore that stock is conceived as both internal and external to the firm.

Secondly, the same KMPs can contribute to a stock of market-based knowledge, concerning the requirements of customers, their behaviour, and the market opportunities which might be feasible in the future.

Thirdly, the KMPs create a stock of knowledge about the administrative, technical and management processes within the organisation itself, through which it identifies and delivers both existing and new products and processes.

Now it is clear that the various histories, choices and circumstances of firms influence the extent to which these three bodies of knowledge are thoroughly articulated and developed. In some companies the technology stock is much more thoroughly developed as a genuine firm resource than in others, largely through the application of Group C1 or C1 and C2 KMPs. In other organisations, the market knowledge stock can be more thoroughly developed; and in others the process knowledge stock is better understood. In addition, there may be marked differences between firms in terms of their focus upon KMPs for accumulating, interfacing or deploying their knowledge bases. Some of the reason for this variation lies in the specific nature of the companies and their industries; but all of them could in principle exploit all types of knowledge base management to a higher degree.

The potential for interaction between the major types of KMP can be illustrated by the case of one company in particular which produces a wide variety of electronic devices. An emergent new model of the strategic mission for the Corporate R&D lab could be discerned in the discussions around KMPs. This took the form of a model in which the lab would try to fully exploit all three types of knowledge base (technology, market and company process), and to **combine** them in such a way as to identify 'new business propositions' for the corporate parent. This is interesting because it is a role for the R&D unit which goes beyond simple innovation, and instead proposes corporate diversification options of strategic significance.

4. Conclusion

The preceding discussion demonstrates that knowledge management practices can vary from firm to firm in their number, detail, and mode of implementation. It also demonstrates that the 'menu' of available KMPs is in principle growing, and that firms can, if they chose, avail themselves of more and more sophisticated knowledge management options, even to the point of having knowledge management 'strategies'.

We have also seen that by focusing on KMPs rather than on the technology itself or on the actual forms of knowledge, we have penetrated quite deeply into both the **current** forms of path dependence in a firm **and** the KMPs which are capable in principle of **changing** the constraints on innovation, and thus **modifying** the path-dependence of a company. This raises the issue, referred to in the introduction, of the potential for variety-generation **within** the

firm. It was pointed out that the tradition evolutionary perspective emphasises the constraints on variety, whereas the new perspectives on knowledge management emphasise the possibility of partially **relaxing** the constraints on variety generation.

The analysis presented above suggests that there is some reason to move partially towards this second point of view. This is a qualified judgement however. Firms are clearly moving at different speeds to adopt new KMPs. Furthermore, it is not clear that all the new KMPs strengthen variety generation. It is possible to imagine a mode of implementing a highly IT-based set of KMPs which lead to a **strengthening** of that part of the knowledge base which maintains the current distinctive technological 'signature' of a firm, and does not promote more variety. Like many other aspects of management activity, the outcome is as much dependent on the implementation of changes as on their intended substance.

If it is true that knowledge management can modify the potential for variety generation within the firm, then this finding has significance for evolutionary economics in general. Currently variety generation is seen very much as a phenomenon linked to populations of firms, and mediated through firm birth and firm death. An increase in the potential for intra-firm variety generation would shift the locus of variety generation away from the population to some extent.

Finally, it seems fruitful to continue to explore these issues through the lens of knowledge management **practices**, rather than only through categories of knowledge or technology[25]. These practices have the advantage that they can be mapped empirically, and that the particular combinations of KMPs in a given firm can be diagnosed and linked to the observed innovative activity. Furthermore, it seems that in mapping KMPs, one is laying bare a dimension of the way firms organise which does not relate mechanically to other reference points for organisation such as money, power or authority. Focusing on KMPs allows us to access the sense in which firms are engaged in *organising* rather that simply exhibiting the properties of an organisation. This is a fruitful research agenda for the future.

Notes

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[1] See I. Nonaka, “A Dynamic Theory of Organizational Knowledge Creation”, *Organization Science*, Vol 5 (1), 1994, pp 14 - 47; Andrew C Inkpen, “Creating Knowledge through Collaboration”, *California Management Review*, Vol. 39 (1), 1996, pp 123 - 140; Chris Marshall, Larry Prusak and David Shpilberg “Financial Risk and the Need for Superior Knowledge Management”, *California Management Review*, Vol. 38 (3), 1996, pp 77 - 101; Economist Intelligence Unit, in co-operation with IBM Consulting Group*The Learning Organisation: Managing knowledge for business success*. (New York: The Economist Intelligence Unit, 1996); Georg von Krogh and Johan Roos (Eds) *Managing Knowledge: Perspectives on cooperation and competition*. (London: Sage, 1996); Annie Brooking, *Intellectual Capital: Core Asset for the Third Millenium Enterprise*. (London: International Thompson Bisiness Press, 1996). [BACK]

[2] In particular see Dorothy Leonard-Barton, *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*. (Boston: Harvard Business School Press, 1995). See also Abdelkader Daghfous and George R. White, "Information and innovation: a comprehensive representation", *Research Policy*, Vol 23, 1994, pp 267-280; Max H. Boisot, "Is your firm a creative destroyer? Competitive learning and knowledge flows in the technological strategies of firms", *Research Policy*, Vol 24, 1995, pp 489-506; Inge C. Kerssens-van Drongelen, Petra C. de Weerd-Nederhof and Olaf A. M. Fisscher, "Describing the issues of knowledge management in R&D: towards a communication and analysis tool", *R&D Management*, Vol 26 (3), 1996, pp 213-229. Many of these discussions are additionally informed by broadly economic perspectives on learning and innovation, especially Wesley M. Cohen and Daniel A. Levinthal "Absorptive capacity: A new perspective on learning and innovation", *Administrative Science Quarterly*, Vol 35, 1990, pp 128-152. [BACK]

[3] Stanley J. Metcalfe and Nico de Liso, "Innovation, Capabilities and Knowledge: The Epistemic Connection", paper presented to the 3rd international conference on Advances in Sociological and Economic Analysis of Technology (ASEAT),

Manchester, September 1995. Forthcoming in *The Organisational Dimensions of Technological Change*, Edited by Rod Coombs, Ken Green, Albert Richards and Vivien Walsh (London: Edward Elgar, forthcoming). [BACK]

4 Nonaka, 1994, op. cit. See also I. Nonaka, "The Knowledge Creating Company", *Harvard Business Review*, No. 69 (1991); and I. Nonaka and H. Takeuchi, *The Knowledge Creating Company: How Japanese Companies Create The Dynamics of Innovation*, (Oxford: Oxford University Press, 1995). [BACK]

5 Leonard-Barton, 1995, op.cit. [BACK]

6 The unit of analysis is important here. Clearly the predominant locus of path dependency is the business unit. But there are also significant elements of path dependency in the behaviour of the firm as a collection of business units. The degree of interaction between these loci of path dependency will be influenced by the corporate management style. These isues are discussed later in the paper. [BACK]

7 This question has recently been given a further dimension in debates on the validity of 'knowledge-based approaches to the theory of the firm'. See Nikolai J. Foss (a), "Knowledge-based Approaches to the Theory of the Firm: Some Critical Comments", *Organization Science*, Vol. 7 (5), pp 470 -476, 1996; Kathleen R. Connor and C. K. Prahalad "A Resource-based Theory of the Firm: Knowledge Versus Opportunism", *Organization Science*, Vol. 7 (5), pp 477 - 501, 1996; Bruce Kogut and Udo Zander "What Firms Do? Coordination, Identity, and Learning", *Organization Science*, Vol. 7 (5), pp 502 - 518, 1996; and Nikolai J. Foss (b) "More Critical Comments on Knowledge-based Theories of the Firm", *Organization Science*, Vol. 7 (5), pp 519 - 523, 1996. The debate centres around the extent to which 'knowledge perspectives' can explain *why firms exist at all*; this has clear implications for the ways in which a 'knowledge perspective' may inform our understanding of the degree of variety generation that may be possible within a firm. [BACK]

[8] In Section 2 of the paper we elaborate on our understanding of knowledge management practices as *routines* within the firm. It is worth pointing out here, however, that there is increasing interest in analysing 'practices' within a number of disciplines. Within sociology, see Stephen Turner, *The Social Theory of Practices: Tradition, Tacit Knowledge, and Presuppositions*, Chicago: University of Chicago Press, 1994. In the history and sociology of science and technology, see Andrew Pickering, *The Mangle of Practice: Time, Agency and Science*, Chicago: University of Chicago Press, 1995. Within social anthropology Jean Lave has suggested a focus on 'communities of practice' (Jean Lave and E. Wenger *Situated learning: Legitimate peripheral participation*, Cambridge: Cambridge University Press, 1991). Lave's ideas are now being utilised by some within organisation studies - see John Seely Brown and Paul Duguid, "Organizational Learning and Communities-of-Practice: Towards a Unified View of Working, Learning and Innovation" *Organization Science*, Vol. 2 (1), 1991, pp 40 -57. [BACK]

[9] Thus we do not base our approach around discussion of the differences between tacit and explicit knowledge. [BACK]

[10] Wendy Faulkner, "Conceptualizing Knowledge used in Innovation: A Second Look at the Science-Technology Distinction and Industrial Innovation", *Science, Technology and Human Values*, Vol 19 (4), 1994, pp 425 - 458. [BACK]

[11] James Fleck and Margaret Tierney, "The management of expertise: Knowledge, power and the economics of expert labour", *Edinburgh PICT Working Paper* No. 29 (Edinburgh: Research Centre for Social Science, University of Edinburgh, 1991). [BACK]

[12] W. Vincenti, *What engineers know and how they know it: Analytical studies from aeronautical history*. (Baltimore: John Hopkins University Press, 1991). [BACK]

[13] Faulkner, 1994, op.cit. [BACK]

[14] See for instance Brian Arthur, “Competing technologies, increasing returns, and lock-in by historical events”, *The Economic Journal*, Vol 99 (1989), pp 116 - 131. [BACK]

[15] See for instance Richard Nelson & Sidney Winter, An Evolutionary Theory of Economic Change (Cambridge, Mass: Harvard University Press, 1982). See also Rod Coombs, Paolo Saviotti & Vivien Walsh "Introduction", in *Technological Change and Company Strategies: Economic and sociological perspectives*, Edited by Rod Coombs, Paolo Saviotti & Vivien Walsh (London: Academic Press, 1992). [BACK]

[16] Metcalfe & de Liso, 1995, op. cit. [BACK]

[17] Geoffrey M. Hodgson "Corporate Culture and the Nature of the Firm", Judge Institute of Management Studies Working Paper No. 14 (1993-94), Cambridge: University of Cambridge. [BACK]

[18] Indeed all 'failed' or aborted attempts at innoavtion would be hidden from view, however interesting in terms of knowledge management. [BACK]

[19] Epistemological, ontological, and indeed political. See for instance:- Frank Blackler, "Knowledge, Knowledge Work and Organizations: An Overview and Interpretation", *Organization Studies*, Vol 16 (6), 1995, pp 1021 - 1046; Craig Pritchard, “A Commentary on ‘Blackler: Knowledge, Knowledge Work and Organizations: An Overview and Interpretation”, *Organization Studies*, Vol. 17 (5), 1996, pp 857-858; Frank Blackler, “Response to Pritchard’s Commentary”, *Organization Studies*, Vol. 17 (5), 1996), pp 858-860. Blackler adopts a focus on ‘knowing’ as an organisational activity (see also Scott D.N. Cook and John Seeley Brown, "Bridging Epistemologies: The generative dance between organisational knowledge and organisational knowing", mimeo, Xerox Palo Alto Research Centre, Palo Alto, California, 1995), precisely because of some of the difficulties of concentrating on knowledge. Some of these difficulties have for many years been highlighted within work on the sociology of scientific knowledge (SSK) - see for instance Andrew Pickering, (Ed) *Science as*

Practice and Culture, (Chicago: Chicago Uniersity Press, 1992). Our focus on knowledge management practices as routines thus steps around many of these difficulties. See also Richard Hull, "The Role of Critique in SSK: Some preliminary excursions", paper presented to the conference, "Is There A Future For SSK", Tavistock Institute, London, September 1996. [BACK]

[20] We are thus developing and considerably refining the ad-hoc broad identification of four critical 'knowledge management processes' by Inkpen, 1996, op. cit. [BACK]

[21] Research is ongoing on detailed case studies of KMPs in the R&D and innovation activities in five companies, supported by the UK Economic and Social Research Council. [BACK]

[22] Typical actors in an R&D setting include R&D scientists, project managers, gatekeepers (formal or informal); library personnel, patent and intellectual property specialists, technical marketing personnel, business development specialists etc. [BACK]

[23] This example is taken from a case study in the R&D labs of a major manufacturer of electronic consumer and capital goods. [BACK]

[24] T. J. Allen, "Communications in the Research and Development Laboratory", *Technology Review*, Vol 70 (1), 1967, pp 31-37. T. J. Allen, *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Innovation within the R&D Organization*, (Cambridge Mass.: MIT Press, 1977). See also Stuart Macdonald and Christine Williams "The survival of the gatekeeper", *Research Policy*, Vol 23, 1994, pp 123-32. [BACK]

[25] This is also in accordance with the observations of Foss, op. cit. 1996a and 1996b, who argues forcibly that 'knowledge-based approaches to the theory of the firm', although interesting, do not provide *sufficient* explanations for the existence of *firms*, rather than other forms of economic organisation such as markets. He further suggests

that the basis of economic organisation may instead be found in the study of contracts and asset ownership. It could be surmised that such a focus would further tend to downplay the possibilities for relaxing the constraints on innovation. [BACK]