2013

Three shapes of organizational knowledge

van den Berg, Herman Anthony

Journal of Knowledge Management, 17:2 (2013), 159-174

Forthcoming in 2013 in Volume 17, Issue 2

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Journal:	*Journal of Knowledge Management*
Manuscript ID:	JKM-Jul-2012-0207.R2
Manuscript Type:	Research Paper
Keywords:	Knowledge management, Knowledge-Based View, Strategic management, Production, Resources, Economic Theory

1. Introduction

In one of his last publications, “The Many Shapes of Knowledge”, Herbert A. Simon (1999) suggested that we are becoming increasingly aware that knowledge plays a central role in economic processes. This realization has called attention to the difficult problem of gauging the cost and value of knowledge as a factor of production. Our inability to accurately measure the cost and value of knowledge presents a grave impediment to the efficient and profitable conduct of business (Simon, 1999).

The purpose of this paper is to examine the extant literature and extract a typology of knowledge that may be fruitful in facilitating research in a knowledge-based view of production (Arrow, 1999). This research is motivated by a desire to improve our understanding of how firms create value and by a desire to advance the development of a strategic theory of the firm using a knowledge-based view (KBV). This research responds to Simon’s (1999, p. 34) challenge to apply “an economic calculus to knowledge”.

The author proposes that for management purposes organizational knowledge, as the paramount input to all production processes, be considered in three separate classifications, tacit, codified, and encapsulated. While the bulk of previous knowledge management theory has generally focused on tacit and codified or explicit knowledge, this paper contributes to the theory by drawing attention to the often under investigated third classification, encapsulated knowledge.

Accurate measurement of the cost of inputs and the value of outputs is important for the effective management of organizations. Accordingly, the cost and value of knowledge needs to be estimated explicitly, to effectively determine the efficiency and profitability of our organizational pursuits. This is difficult to do, because knowledge is abstract and conceptual, unlike production machinery, which, being concrete and tangible, can be relatively easily costed and valued (Simon, 1999). Nevertheless, the urgency of competently measuring the cost of knowledge increases as the productivity of our organizations and economies become increasingly knowledge-dependent (Simon, 1999, p. 34). Failure to measure the costs and value of knowledge dooms us to compete with obsolete strategies and tactics (Boisot, 1998).

Before the cost or value of knowledge may be measured, it is necessary to define what is meant by knowledge. Epistemologists have been struggling with defining the concept for thousands of years, yet a universally accepted definition of knowledge has not surfaced. It would be the height of pretension to assume that what has occupied great minds for eons could be swiftly resolved here. For the conduct of business and for empirical research in KBV, however, some operational notion of knowledge is required. Bollinger and Smith (2001) and Goh (2002) suggest that knowledge is a strategic asset. Grant (1996) goes further, suggesting that knowledge is the most strategically significant resource of the firm. These notions of knowledge may therefore be considered an extension of the resource-based view of the firm (Eisenhardt and Santos, 2002). While this is not the only representation of knowledge in the strategy field, empirical literature

has largely focussed on the perception of knowledge as simply a resource (Eisenhardt and Santos, 2002).

Arguably though, knowledge is not merely a strategically significant resource – it is the condicio sine qua non (essential condition) that confers resources with strategic significance. Knowledge is a meta-resource since it transcends basic resources and is the unique source of economic growth and value. Resources are defined by knowledge of them, rather than by their physical attributes (Lee, 1991). “Economic growth occurs whenever people take resources and rearrange them in ways that are more valuable” (Romer, 1993, p. 184).

In the middle of the last century, the Austrian economist von Hayek had already called attention to the importance of knowledge in economics and the merits of giving it greater analysis in research. He took issue with the unexamined assumption in neo-classical economics that knowledge was pervasive and costless (von Hayek, 1945). He also suggested that distinctions between various types of knowledge needed to be made and explored:

“Clearly there is… a problem of the *Division of Knowledge* which is quite analogous to, and at least as important as, the problem of the division of labour. But while the latter has been one of the main subjects of investigation ever since the beginning of our science, the former has been as completely neglected, although it seems to me to be the really central problem of economics as a social science” (von Hayek, 1937, p. 49) (emphasis in original).

Consideration of the various shapes or classifications of knowledge is also an essential part of specifying an operational definition of knowledge. This paper examines the literature of the knowledge-based view of the firm and, drawing on that literature, suggests a working definition of organizational knowledge, and settles on three classifications or shapes of knowledge that differ along six salient perspectives. Differences between the three classifications along the six perspectives have strategic implications for the firm.

The remainder of this article is divided into seven sections. Next (section 2) is a brief discussion of specialization as a partitioning of knowledge and its fundamental role in our understanding of a KBV theory of the firm. Following that is a section (3) that suggests characteristics of specialized knowledge affect its transfer within organizations and across organizational boundaries. The subsequent section (4) argues that knowledge is *the* resource of interest, permeating all other 'resources'. Next is a section (5) discussing the difference between two shapes of knowledge: information as codified knowledge and know-how as tacit knowledge follows. The section thereafter (6) outlines how the paradox of knowledge replication suggests a third shape of knowledge – an encapsulated form. The issue of appropriation of the value of knowledge is also discussed in this section. The subsequent section of this paper (7) offers a definition of organizational knowledge and suggests a typology for advancing KBV research, classifying of knowledge as tacit, codified, or encapsulated. It continues with discussions of, the nature of organizational knowledge and provides operational definitions for tacit, codified, and encapsulated knowledge.

The paper concludes with a brief discussion (section 8) of contributions and limitations

2. Specialization and Productivity

That knowledge used in production has various shapes or classifications proceeds logically from observations that individuals, as well as firms, specialize. Specialization results in divergent courses of knowledge acquisition being taken, and it generates and reinforces comparative advantages. While the literature on specialization does not set out general classifications of knowledge, it does suggest that partitioning of knowledge is fundamental to our understanding of a theory of the firm.

The idea that specialization is productive is generally attributed to Adam Smith in his discussion of the division of labour among individual workers within a firm. Demsetz (1988, 1991) extends Adam Smith's idea to consider productive specialization among firms, suggesting that firms, like individuals, can improve their economic prospects through specialization in knowledge acquisition. Firms are "repositories of specialized knowledge and of the specialized inputs required to put this knowledge to work" (Demsetz, 1988, p. 158). Hence, "Economic organization, including the firm, must reflect the fact that knowledge is costly to produce, maintain, and use [and that] …there are economies to be achieved through specialization" (Demsetz, 1988, p. 158). The division of knowledge facilitates human-capital deepening and furthers the division of labour, which in

turn leads to increased productivity and economic efficiency (Becker and Murphy, 1992, Demsetz, 1988, 1991, Grant, 2002).

Demsetz (1988) essentially argues that Adam Smith's observations regarding specialization by individuals has a parallel application when firms are considered the unit of analysis. Demsetz defines the firm as "an agreement to *specialize*" (1988, p. 156) (emphasis in original). And specialization is defined as the production for persons who are not members of the firm's team. This distinguishes specialization from self-sufficiency, which, at the other end of the specialization-generalization spectrum, implies production by and for the same person. This characteristic of the firm is consistent with price theory in which the firm does not consume what it produces, but sells it to others (Demsetz, 1988).

The economic value of specialization and its knowledge-based origin has also been recognized in labour economics. Nobel laureate Gary S. Becker and co-author Kevin M. Murphy (1992, pp. 1138-40) argue that specialization maximizes comparative advantage. The issue of specialization has historically been analysed from a physical labour perspective, beginning with Adam Smith's discussion of pin making. Becker and Murphy extend Smith's discussion by focusing on the specialization from a knowledge perspective, suggesting, "Specialization is what produces most comparative advantage… [and] much of the growth in specialization over time has been due to an extraordinary growth in knowledge" (1992, pp. 1140, 45).

Grant (2002, p. 112) reiterates Demsetz's (1988) assertion that specialization defines the firm. According to Grant (2002, p. 112), the firm exists because it provides "conditions under which individuals can integrate their specialist knowledge" and because knowledge for production "requires greater specialization than is needed for its utilization". This difference between knowledge required to produce, and knowledge required to use, a product is termed the "fundamental asymmetry in the economics of knowledge" (2002, p. 112). Grant goes so far as to claim that "[t]he assumptions that there are gains from specialization in knowledge acquisition and storage, and that production requires the input of a wide range of specialized knowledge… is fundamental to *all* theories of the firm" (2002, p. 112) (emphasis added).

3. Transference of Knowledge

The repository chosen for an assemblage of specialized organizational knowledge affects it transferability. "Knowledge properties affect… how easily it diffuses within and across firm boundaries" (Argote *et al.*, 2003, p. 574). The knowledge-based view assumes, among other things, that the transference of tacit knowledge (skills, know-how, and contextual knowledge) is costly and slow, being only manifest in application, while transference or communication of explicit knowledge between individuals and organizations is easy (Grant, 2002). The transfer of tacit knowledge requires a greater degree of intimacy and permanence than does the transference of codified or encapsulated knowledge (Hedlund, 1994). The attributes of knowledge also, in part, affect the decision to

transfer knowledge (Kogut and Zander, 1992, Teece, 1996, 1998, Zander and Kogut, 1995).

Two of the attributes of knowledge identified by Kogut & Zander (1992) as impacting the costs of knowledge transfer are codifiability and complexity. Codifiability, refers to the difficulty of a firm in structuring knowledge "into a set of identifiable rules and relationships that can be easily communicated" (Kogut and Zander, 1992, p. 387). Increasing codifiability decreases the cost of knowledge transfer.

The second characteristic of knowledge impacting transfer is complexity. Complexity may be considered an increasing function of the number of operations or steps required to solve a task or the number of parameters defining a system (Kogut and Zander, 1992, p. 387). Increasing complexity increases the cost of knowledge transfer.

Codification and complexity are not independent characteristics of knowledge. Progress in knowledge codifiability has the potential to offset increasing costs of knowledge transfer attributable to mounting knowledge complexity.

4. Knowledge Defines a Resource

That knowledge is transferrable suggests that it may be considered a resource or factor of production. Grant suggests that a "focus on the role of knowledge as a factor of production" (2002, p. 133) unifies the knowledge-based view of the firm.

Drucker (1993) and Arrow (1999) have also proposed that knowledge be considered as a factor of production.

The knowledge-based view of the firm arguably completes the resource-based view of the firm: "Knowledge, in fact, *is an additional and necessary dimension attaching to every resource*. Without the 'knowledge' of how to profitably use a resource, it is not a resource, it has no value. Resources without knowledge have no meaning" (Lewin and Phelan, 2000, p. 71) (emphasis in original). Knowledge may therefore be considered the meta-resource that coordinates the mobilization of all other organizational 'resources' (Choo and Bontis, 2002).

For resources to confer competitive advantages, they must be imperfectly imitable (Barney, 1991). The knowledge a firm has about the coordination, combination and application of its resources may, in itself, be its most unique and inimitable resource. This is especially the case if the firm's other resources are lacking in distinctiveness (Grant, 1996, Penrose, 1959). Knowledge, particularly in its tacit form, is arguably the most inimitable resource because of, among other things, its nested heterogeneity (Felin and Hesterly, 2007), causal ambiguity (Lippman and Rumelt, 1982), and the time compression diseconomies it engenders (Dierickx and Cool, 1989).

5. Information as Codified Knowledge and Know-how as Tacit Knowledge

The inimitability of knowledge depends on its shape. Information and know-how are informal designations for two shapes of knowledge: codified and tacit, respectively. An important characteristic of information is that it can be transmitted at low cost and "without loss of integrity" because the pattern of formation or rules governing the formation of statements, or language and grammar is commonly known or standardized between sender and recipient (Kogut and Zander, 1992, p. 386).

Information may also be defined as structured and formatted data sets that require knowledge to interpret and process them (Boisot, 1998, Cowan *et al.*, 2000, David and Foray, 2002). Information remains inert until acted upon by a knowledgeable agent whose cognitive context imparts it with meaning (Cowan *et al.*, 2000, David and Foray, 2002). David and Foray also emphasize information's low cost of replication (2002).

Know-how, on the other hand, is practical skill or expertise permitting efficient execution and must be learned and acquired or accumulated over time through experience (Kogut and Zander, 1992, von Hippel, 1988). Possession of this category of knowledge empowers an agent to mental or manual action, and may be thought of as cognitive capacity (David and Foray, 2002). The replication of know-how is an expensive undertaking for both the firm and the individual due to the difficulty of explicitly articulating what it is we know (David and Foray, 2002).

The key differences between the two categorizations have significant economic ramifications. Information is the focus of pricing in the economics of exchange, while know-how is the focus in transforming inputs into outputs in the economics of production (Kogut and Zander, 1992).

Choo, drawing on Polanyi (1966) and Nonaka and Takeuchi (1995), distinguishes between tacit knowledge as “knowledge that is uncodified” (1998, p. 111), and explicit knowledge as “knowledge that can be expressed formally using a system of symbols” (1998, p. 112). Choo also includes object-based knowledge, “found in artifacts such as products” under the heading of explicit knowledge (2006, p. 141).

The term explicit, however, implies observability, and not all non-tacit knowledge is observable. Observability has important implications for transferability, replication and appropriation of value. Choo (2006), for example, recognizes that object-based explicit knowledge may remain unobservable unless it is unpacked through reverse engineering, inspection, or compositional analysis. In congruence with the arguments in the preceding section, it may therefore be useful to distinguish between non-tacit knowledge that is codified and observable and non-tacit knowledge that is encapsulated and not readily observable.

6. The Paradox of Replication drives Knowledge Encapsulation

Despite imperfect imitability, firms seek to replicate knowledge within their boundaries. Unless a firm is able to increase the knowledge of its individuals or convert its skills into ‘organizing principles’, it will forever remain a small craft

shop (Kogut and Zander, 1992). The paradox of replication is that advantages achieved through reductions in the cost of intra-firm knowledge transfer, say through codification, also increase the risk that competitors will appropriate such knowledge.

While firms may desire to codify their knowledge to increase internal efficiency, doing so also increases appropriability of that knowledge by external parties. An alternative to codification is the encapsulation of knowledge. Kogut and Zander (1992) provide the production of software code as an example of knowledge encapsulation. Encapsulation consists of the transformation of substantive knowledge into a product that requires only functional knowledge for its utility.

Software, for example, provides utility because it is encapsulated. The user of software is only required to understand the function of the program and avoids the cost of acquiring the knowledge of software production. "[T]he possibility to separate the expertise to generate the technology and the ability to use it… permits the *nesting* of a firm's knowledge" (Kogut and Zander, 1992, p. 390) (emphasis added).

Kogut and Zander's (1992) reference to 'nesting' a firm's knowledge and saving the user the cost of acquiring the substantive knowledge of production resonates with Demsetz's (1988) emphasis on knowledge encapsulation to achieve an economic market exchange. Teece's (2000) reference to the need to embed know-how to enable extraction of value reinforces this concept. Osterloh and Frey (2000) go so far as to claim that, "[t]acit knowledge can be efficiently

marketed *only* if it is encapsulated…" (emphasis added). These references suggest that it may be constructive to consider knowledge organized in an encapsulated configuration as a classification of knowledge distinct from codified knowledge.

The appropriation of value is facilitated when knowledge is encapsulated because codifiability and complexity of knowledge limit the appropriability of value from information and know-how, respectively. Appropriability, as it is used here, refers to the ability of the owner of an economically valuable assemblage of knowledge to realize the value of that knowledge (Grant, 1996). The encapsulation of complex tacit know-how in a product permits its indirect appropriation (Grant, 1996). Appropriating value from codified knowledge, or information, is on the other hand difficult since it is both a public and non-rivalrous good (Langlois and Robertson, 1996). The public nature of information means that others cannot be kept from using it (or made to pay for it) once it has been made available. The non-rivalrous nature means that one person's use of the information does not make it less available to others. These two characteristics of information or codified knowledge essentially preclude appropriability in markets, absent a strong intellectual property rights regime.

7. An Operational Definition of Knowledge

The following is offered as an operational definition of knowledge: *the value-endowing meta-resource that arises from thought, reflection, or experience.* This definition is modeled on Grant's concepts and those described in the preceding

sections. Describing knowledge as 'value-endowing' is a recognition that it has strategic significance (Grant, 1996, p. 375), and gives emphasis to the economic importance of knowledge as a firm asset (Boisot, 1998, Teece, 1998, 2000). The adjective, 'value-endowing', does not preclude the likelihood that separate evaluators will assign different valuations to any particular knowledge asset since valuations tend to be context specific (Starbuck, 1992).

Defining knowledge as a 'meta-resource' means that it is at a higher level of what is typically considered a resource, while retention of the word, 'resource', signifies that it has an important role in sustaining the competitive advantage of firms. Just as 'meta-data' is above, and descriptive of, data, knowledge defined as a 'meta-resource' suggests that it confers value and meaning to all resources.

Describing knowledge as being derived from 'thought, reflection or experience' pays homage to both rationalist and empiricist approaches to knowledge, and recognizes that both may be value endowing. This description recognizes that value may be derived from experience or thought. It also pays tribute to the strategic management literature that emphasizes the process of knowing. According to Zack (1999, p. 46), "Knowledge can be understood as both a thing… and as a process of… knowing… [O]rganizations need to manage knowledge both as object and process."

7.1. Typology of Organizational Knowledge

The extant literature suggests that organizational knowledge may be categorized as belonging to one of three classifications: tacit, codified, and encapsulated.

This typology for knowledge has been highlighted because differences between each form, along a number of perspectives, have strategic implications for a firm. The choice of what combination of each type of knowledge is applied within various stages of production may reasonably be expected to impact performance. Some empirical evidence suggests that specific combinations of tacit and codified knowledge, described as "a 'focused codification strategy',… greatly facilitates knowledge flows and thereby can help to boost performance of companies" (Schulz and Jobe, 2001, p. 161).

Boisot (1998, pp. 12-13) describes three repositories of knowledge that economize on the use of physical resources, knowledge residing in individual brains, knowledge codified as information, and knowledge embodied in physical artefacts. He uses the construction of a building as a metaphor for distinguishing between them. The accumulated stock of knowledge of human behaviour in space, and of the physical properties of materials, used by the architects in drawing the buildings plans is an example of the first repository. Construction drawings and plans are examples of the second, and a shaped brick used in constructing a building is an example of the last (Boisot, 1998). Based on these distinctions as well as those of Polanyi (1966), Kogut and Zander (1992), Nonaka (1994), Choo (1998), and others, organizational knowledge may be classified as tacit, codified, or encapsulated.

Each of these three classifications of knowledge differs along a number of dimensions that have strategic and economic implications. Tacit knowledge, for example, as practical skill or expertise permitting efficient execution, must be

learned, acquired, and accumulated through experience (Nelson and Winter, 1982, Winter, 1987). Tacit knowledge may also be considered procedural know-how (Kogut and Zander, 1992). It has the unique characteristic of being absolutely necessary to interpret and process the structured and formatted data sets that constitute codified knowledge (Boisot, 1998, Cowan *et al.*, 2000, David and Foray, 2002). It is also expensive to transfer and diffuse requiring complex structures of interaction (Choo, 2002).

Codified knowledge has the unique attributes of being non-rivalrous and non-excludable (Langlois and Robertson, 1996, Saviotti, 1998). Unlike tacit knowledge, codified knowledge may be very inexpensively replicated, transferred and diffused (Boisot, 1998, Heiman and Nickerson, 2004, Romer, 1990). The codification of knowledge facilitates inexpensive intra-firm knowledge transfer, but also increases the risk of misappropriation outside the firm. Accordingly, firm boundary decisions are strongly influenced by strategic consideration of imitability and replicability of codified knowledge (Teece, 1998).

Encapsulated knowledge differs from both tacit and codified in its eminent marketability (Osterloh and Frey, 2000, Teece, 2000). Knowledge encapsulated in artefacts' design and functionality minimizes the cognitive load on users (Gorga, 2007). While the value of codified knowledge may be easily misappropriated absent a strict intellectual property regime, the value of encapsulated knowledge is readily appropriable through the sale of commercially valuable items or devices (Demsetz, 1988, Teece, 2000). The encapsulation of

knowledge facilitates the retention of complexity, a complexity that is necessarily reduced when knowledge is codified.

Tacit, codified, and encapsulated knowledge differ along a number of strategically important perspectives. The costs and benefits of any given productive activity may therefore depend on the unique combination of tacit, codified and encapsulated knowledge chosen as factor inputs to production. It is therefore reasonable to expect firms to select those combinations of tacit, codified, and encapsulated knowledge-based factors of production that they find most economic. It is likewise reasonable to expect that different stages of production along a value chain will often rely on different combinations of tacit, codified, and encapsulated knowledge.

Table 1 overlays Boisot's (1998) three distinctions of knowledge on the dichotomous tacit/explicit models suggested by Polanyi (1966), Nonaka (1994), and Choo (1998), and the know-how/information model of Kogut and Zander (1992). Knowledge residing in individual brains (Boisot, 1998) corresponds to tacit knowledge (Choo, 1998, Nonaka, 1994, Polanyi, 1966), while explicit knowledge (Choo, 1998, Nonaka, 1994, Polanyi, 1966) is may be bifurcated into either knowledge codified as information or knowledge encapsulated in a physical artefact (Boisot, 1998). Similarly, know-how (Kogut and Zander, 1992) may be split into knowledge that either resides in individual brains or is nested in physical artefacts (Boisot, 1998).

Insert Table 1 about here

7.2. The Nature of Organizational Knowledge

The three classifications of knowledge, tacit, codified, and encapsulated, differ along a number of fundamental attributes that undergird all forms of substantive knowledge. Table 2 provides six dimensions or perspectives that may be useful as an aid in determining the most fitting classification for categorizing a specific assemblage of knowledge. They were chosen on the basis of their strategic and economic significance to a firm. For example, the degree to which knowledge is tacit has significant implications for the location of firm boundaries:

"…[B]oundary issues (such as vertical integration) are… strongly influenced by tacit knowledge and imitability/replicability considerations. …[T]he tacit component of knowledge cannot frequently be transferred absent the transfer of personnel and organizational systems/routines. Tacit knowledge and its transfer properties help determine the boundaries of the firm…" (Teece, 1998, pp. 75-76).

Differences in relative reliance on tacit, codified, and encapsulated knowledge, as characterized in Table 2, may be fundamental in determining relative productivity between firms. Productive activity may be consist primarily of the transformation of tacit knowledge into some form of explicit knowledge (Hedlund, 1994). Nevertheless, few if any stages of production rely exclusively on tacit, codified or encapsulated knowledge. After all, "…there is a limit to the extent to which one factor of production can be substituted for another…" (Robinson, 1933, p. 330).

It is possible that a specific incorporation of knowledge may not clearly fall into one of the three chosen classifications. It may therefore be more useful to think of a given assemblage of knowledge as having attributes or dimensions that place it predominantly in one classification rather than in another, instead of exclusively designating it to one classification (Saviotti, 1998).

Insert Table 2 about here

Each of the dimensions or perspectives used to classify knowledge has strategic implications for the firm. For example, tacit knowledge must be 'rented' from a firm's employees, suppliers, and perhaps customers. The firm cannot really own it. Codified knowledge is to a large extent commonly held, and that which is not, is subject to misappropriation absent a strong intellectual property rights regime. Encapsulated knowledge comes closest to describing a finished product for end-user consumption. Its value lies in the design and functionality delivered by the substantive knowledge concealed within it.

7.3. Tacit Knowledge

Tacit knowledge may be defined as *the value endowing meta-resource originating from thought, reflection, or experience that remains resident in the human mind*. This definition considers tacit knowledge to be shaped as a meta-resource "held by a knowing agent" (Boisot, 1998, p. 12). An organization's members implicitly use this knowledge as they perform their skills since it

remains resident in the human mind (Choo, 2002). This knowledge may be gained by experience that is often incommunicable and only evident as it is expressed or practiced by its possessor (Spender, 1996).

Tacit knowledge may be considered more valuable than codified or encapsulated knowledge because it forms the basis for their derivation. Both codified and encapsulated knowledge ultimately originate from tacit knowledge. Tacit knowledge may have value independent of the other two classifications of knowledge, but neither codified nor encapsulated knowledge have value in the absence of tacit knowledge. For value to be derived from either codified or encapsulated knowledge, tacit knowledge must be brought to bear. “Deprived of their tacit co-efficients, all spoken words, all formulae, all maps and graphs are strictly meaningless.” (Polanyi, 1969, p. 195).

7.4. Codified Knowledge

Codified knowledge may be defined as *the value endowing meta-resource originating from thought, reflection, or experience that is expressed as information using systems of symbols*. This definition considers codified knowledge to be shaped as a meta-resource “abstracted, and incorporated in check-lists, manuals, blueprints, computer programs, etc.” (Zollo, 1998, p. 26). The term, ‘codified knowledge’ is used in this paper to describe information to recognize that it originates from tacit knowledge (Saviotti, 1998). The unique value of codified knowledge lies in its eminent replicability (Teece, 2000).

7.5. Encapsulated Knowledge

Encapsulated knowledge may be defined as *the value endowing meta-resource originating from thought, reflection, or experience that is embedded in an artefact's design and functionality*. This definition considers encapsulated knowledge to be shaped as a meta-resource "embedded in physical assets, such as machines or products" (Gorga, 2007, p. 18). Encapsulated knowledge may be considered an underdeveloped concept in the knowledge-based view of the firm since it is often subsumed in the more general term, explicit knowledge. Encapsulated knowledge is not exactly explicit because it is knowledge concealed from its users, and explicitness implies observability. Encapsulated knowledge's obscurity has implications for value appropriation. Encapsulation of knowledge enables the appropriation and transfer of value by means of market transactions. While the observability of explicit codified knowledge makes it susceptible to misappropriation (Teece, 2000), the concealed nature of encapsulated knowledge limits misappropriation (Teece *et al.*, 1997).

Management literature hints at the distinct shape of encapsulated knowledge as that which is "embodied in an item or device" (Teece, 2000, p. 37), "being imbedded either in machines and other physical technology" (Langlois, 2001, p. 82), and built up in "the information structures latent in physical things" (Boisot, 1998, p. 13). According to Teece (2000), to be valued commercially, knowledge must generally be encapsulated in some way in a product.

A desire to transfer knowledge inexpensively motivates both codification and encapsulation of knowledge. Codification tends to reduce complexity, while encapsulation allows for the preservation of complexity. Encapsulation of knowledge creates value by making irrelevant the possession of substantive knowledge in the functional use of a product. Encapsulation substitutes for the need to have substantive knowledge (Gorga, 2007). The substantive knowledge of how a computer or an automobile runs is not needed by the user for him or her to realize utility (Pfaffmann, 1998, 2000).

Note, only in a few exceptional situations will production not rely upon some combination of tacit, codified, and encapsulated knowledge. In the vast majority of cases, a mixture of all three knowledge-based factors will contribute to production.

7.6. Software and Music as Examples

Table 3 provides two examples of assemblages of knowledge and how they may be classified as tacit, codified, or encapsulated.

Insert Table 3 about here

The knowledge that is classified as tacit in Table 3 is located in the mind of the producer (programmer or musician). As outlined in Table 2, this classification of knowledge i) may transferred by teaching and example, ii) may be acquired by a student through experiencing and imitation, and iii) may be evinced by a co-

located observer. The knowledge that is classified as codified in Table 3 is comprised of a systematized set of symbols. As described in Table 2, this classification of knowledge is i) easily and inexpensively replicable, ii) valuable because it informs, and iii) permits many to simultaneously enjoy its benefits. The knowledge that is classified as encapsulated in Table 3 is embedded in a physical artefact. As described in Table 2, this classification of knowledge is i) hidden from its users, ii) costly for most to replicate, and therefore eminently marketable.

8. Discussion

8.1. Contribution

This paper contributes to knowledge management theory by identifying, distinguishing, and accentuating encapsulated knowledge as a knowledge-based factor of production distinct from tacit and codified knowledge. This is accomplished by clarifying the distinctions between tacit, codified, and encapsulated knowledge along six perspectives or dimensions: locus or knowledge substrate, transferability, expression, acquisition process, source of economic value, and observability. The paper also defines organizational knowledge as a meta-resource and argues that it is knowledge that confers strategic significance to all resources. Distinguishing between the three shapes of knowledge lays a foundation for the measurement of knowledge as a factor of production and addressing Simon's (1999) challenge of applying an economic calculus to knowledge.

The paper provides a review of the enduring literature to delineate three distinct knowledge-based factors of production, setting the stage for addressing Simon's (1999) challenge of applying an economic calculus to knowledge. It includes an extensive examination of KBV-related papers and monographs and emphasizes the work of a number of researchers in the fields of economics and strategy. The main contribution of this paper is the identification, differentiation, and accentuation of encapsulated knowledge as a classification of organizational knowledge distinct from tacit and codified/explicit knowledge. Distinctions between the three classifications of organizational knowledge are made along a number of dimensions. Defining organizational knowledge as a meta-resource or essential condition for specifying strategic significant resources, and distinguishing between its three shapes lays a foundation for the measurement of knowledge as a factor of production.

The distinctions between the three classifications of knowledge, while presented as being clearly discernible in theory, may be less defined in practice. In practice, the classification of knowledge in which a specific assemblage of knowledge falls is dependent on the tacit knowledge being applied by the user. For example, a software program may be encapsulated to a retail user, but codified to its creator. The omission of any discussion of this conundrum is the main limitation of this paper.

8.2. Implications for Practitioners and Researchers

An awareness, recognition, and appreciation of the differences between the three shapes of organizational knowledge could help practitioners in four ways. First, an appreciation of the differences between the three shapes of knowledge could assist practitioners in determining the most economic combination of knowledge to use in production. As technology progresses, it may become economical to produce with reduced reliance on lower-intensity tacit knowledge (manual labour, for example) and increased reliance on encapsulated knowledge in combination with higher-intensity tacit knowledge (machine and operator, for example).

Second, an appreciation of the characteristics between the transferability of knowledge could direct practitioners to consider ways to transfer knowledge more effectively within and across organizational boundaries. The need to transfer complex, difficult to articulate, tacit knowledge between internal organizational units may suggest a transfer of personnel between the units. On the other hand, the need to transfer knowledge that is readily codifiable may suggest the implementation of a simpler communication system.

Third, appreciating differences between firms in productive use of tacit, codified, and encapsulated knowledge could assist practitioners in the determination of the most economic location of firm boundaries. Differences in knowledge productivity along a value chain between raw material suppliers and ultimate consumers may suggest that intermediation (for example, by distributors, wholesalers, retailers) may prove beneficial.

Finally, an appreciation by practitioners of the distinct shapes of knowledge could help ensure that value generated in production is appropriated for the firm. In some cases a firm may be able to maximize profit by licensing codified knowledge, but in other cases, where the excludability is limited, a firm may be better off encapsulating and concealing knowledge in a saleable artefact.

For knowledge management researchers, it becomes important to move beyond the dichotomous tacit/explicit paradigm and recognize encapsulated knowledge as a distinct form of organizational knowledge that is neither tacit nor explicit. Knowledge that is encapsulated is not explicit, but often incomprehensible, to ultimate consumers who make functional use of it. Encapsulated knowledge facilitates the retention of complexity that may only be made explicit through reverse engineering, inspection, or compositional analysis (Choo, 2006). The identification, distinction, and accentuation of encapsulated knowledge can aid researchers in better understanding of how firms create value and assist us in advancing the development of a strategic theory of production using a knowledge-based view. In congruence with the arguments in the preceding section, it may therefore be useful to distinguish between non-tacit knowledge that is codified and observable and non-tacit knowledge that is encapsulated and not readily observable.

8.3. Limitations to Research and Findings

Many others have contributed to the richness of the knowledge-based view of the firm from related or different perspectives, beyond that which is presented here.

Limitation of time and space preclude examination of all contributions to KBV. Some of these seminal works include von Hayek's (1945) assertion that the economics is a problem of knowledge utilization, and Arrow's (1974) observation that "the scarcity or information handling ability is an essential feature for the understanding of… organizational behavior" Other works include those that discuss the broad topics of knowledge creation (Nonaka, 1994), knowledge assimilation (Cohen and Levinthal, 1990), and knowledge recombination (Antonelli *et al.*, 2010, Krafft and Quatraro, 2011, Quatraro, 2011, Saviotti, 2004).

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Table 1: Three classifications of knowledge

Tacit	Codified	Encapsulated	
Knowledge residing in individual brains	Knowledge codified as information	Knowledge embodied in physical artefacts	(Boisot, 1998)
Tacit knowledge	Explicit knowledge	Explicit knowledge (found in artefacts)	(Polanyi, 1966), (Nonaka, 1994), (Choo, 1998)
Know-how	Information	Know-how (nested)	(Kogut and Zander, 1992)

Table 2: Classifications of knowledge by perspective

Perspective	Tacit	Codified	Encapsulated
Locus or knowledge substrate (Boisot, 1998, p. 156)	Human mind; "Tacit knowledge probably comes packaged most efficiently in the form of individuals" (Hedlund, 1994, p. 79)	Signs, symbols, codes and display rules	Concealed in an artefact's design and technology; imbedded in machines and other physical technology (Boisot, 1998, p. 156, Gorga, 2007, Grant, 1996, p. 112, Langlois, 2001)
Transfer and diffusion (Choo, 2002, p. 265)	Difficult to verbalize; requires "rich modes of discourse" (Choo, 2002, p. 265) and "physical co-presence" (Boisot, 1998, p. 46); requires some "intimacy and permanence" (Hedlund, 1994, p. 79); costly to diffuse broadly	Easy and low cost transfer and storage; subject to involuntary transfer; requires common 'language'	Speed, extent, and cost of transport all dependent on physical characteristics
Expression	Implicit in action-based skills (Polanyi, 1966) and conversation (Simon, 1999)	Rules, routines and recipes based on a system of symbols (Nelson and Winter, 1982)	Embodied in artefacts (Boisot, 1998, Langlois, 2001); "a tangible product is knowledge in a highly articulated form" (Hedlund, 1994, p. 79)
Acquisition Process	Experiencing and doing, observation and imitation, costly internship and apprenticeship (Nelson and Winter, 1982); "…teachable even though not articulable" (Winter, 1987, p. 171)	Interpretation of signs, symbols, codes, and displays; dependent on IPR regimes	High inherent tradability (Teece, 1998)
Source of Economic Value	Capacity to make intuitive judgements, discoveries and innovations	Informing the interpreter; Low cost replication; non-rivalrous nature (Heiman and Nickerson, 2004, Romer, 1990)	Function of the artefact without requiring substantive knowledge; consumption; appropriability (Demsetz, 1988, Teece, 2000)
Observability	Requires co-location	Limited excludability (Langlois and Robertson, 1996, Saviotti, 1998)	Requires costly experimentation and reverse engineering (Teece *et al.*, 1997)

Table 3: Examples of classified assemblages of knowledge

Assemblage of Knowledge	Tacit Knowledge	Codified Knowledge	Encapsulated Knowledge
Software program	Tacit knowledge is applied by the programmers writing the software and required by users to employ features encapsulated in the program.	The software program's code may be considered codified knowledge by its creator (and those programmers with the tacit knowledge required to make sense of the code).	Software programs may be classified as encapsulated to users. There is no need for users to understand how the programs are coded, how it accomplishes its tasks, or the language used in its development. The software's economic value to its users is in the circumvention of knowing how to write code and to the programmers in being able to appropriate the fruits of their labour.
Music	Tacit knowledge is applied by musicians making music.	A musical score may be considered codified by those composing it and those able to read it.	A piano may be classified as encapsulated knowledge. How it is constructed to emit certain sounds is hidden from the pianist in the design and functionality of the instrument. The piano's economic value (to a pianist) comes from both not having to know how to build one to enjoy its benefits and (to a piano maker) from being able to sell one's piano building skills.