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How to Define and Measure Knowledge for the Analysis of Competitiveness

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Abstract. Linking creation, use, and transfer of knowledge to a company's economic performance remains an important, yet little studied area of academic research. In this article, I extend MERITUM Project objectives that seek standards upon which to measure intangible assets. This is important because of the firm's need to measure and identify intangible assets like knowledge thereby increasing competitiveness. A firm engaged in the production of steel jackets for the offshore oil industry in peripheral Norway is used as a case study in which to develop definitions and metrics of knowledge for the analysis of competitiveness. The company under examination has about 600 employees, an annual production value of about 200 million USD, and seeks to acquire and develop knowledge capital by looking at three key factors including identification (what are the central knowledge processes that take place?), measurement (what kind of indicators can be used?) and management (how is management of knowledge integrated in the general management of the firm?). Results suggest that it is possible on the firm level to link knowledge to competitiveness in a manner in which management can use it as a strategic device.

1. Introduction

In the research literature and in public debate there have been many attempts to define what can be included in the concept of a knowledge based economy. From one point of view knowledge can be looked upon as a commodity that can be bought and sold within a market economy. Another perspective is how knowledge is created and exchanged within a company, between companies, between companies and research institutions, and between companies and other parts of society. A third perspective relates to how the dissemination of knowledge actually takes place and how the development of information and communication technology has an impact on the speed, volume and content of the exchange of knowledge.

The systems of production in both private and public sectors have developed in such a way that it has become increasingly important to more closely investigate how the concept of knowledge, as a factor of production, has developed compared to other factors such as physical capital, labour and raw materials. In 1996, OECD published a study that analysed trends in the historical development of knowledge based economies over the last 20 years. Here, knowledge economies were defined as:

> *"Economies which are directly based on production, distribution and use of knowledge and information" (OECD 1996).*

In earlier analyses of growth in developed countries, one of the main results has been that labour and capital played a central role in explaining economic growth, while other factors of production such as organisation, technology and knowledge also played a part. One assumption made was that producers combined factors of production optimally and that the necessary knowledge on how to do this was available.

In traditional macroeconomic growth theory, little emphasis was put on the analysis of the creation of

knowledge until 1990, when Romer (1990) first introduced his concept of endogenous growth theory. This shift in perspective had a great influence on growth theory, its empirical analysis, and application through public policies that act to stimulate regional economic growth.

Schumpeter (1943) made new developments in innovation theory emphasizing the ability and possibilities of the entrepreneur to create new development. Schumpeter used the concept of innovation related to:

- new products
- new production processes
- new materials
- new organisation of the production process
- new markets

Schumpeter pointed out that new knowledge often was important for innovation, but that this was not the situation for every new innovation. He also stressed that distribution of existing knowledge and development of new knowledge was vital to innovation. This line of thought was picked up again in the 1990s where emphasis on networks, facilitated by information and communication technologies (ICT), was the focus of theoretical debates and case studies.

2. Knowledge transfer

Knowledge transfer is a central process taking place in many parts of society. Significant discussion and research focuses on how knowledge transfer takes place in education. In economics, Marshall in his "Principles" (Marshall 1890), spoke about knowledge transfer as an important issue in explaining external economies. In neoclassical theory, knowledge, as the other factors of production was assumed to be evenly distributed because of the functioning of the market. Hirschmann and Myrdal argued for the doctrine of unbalanced growth and uneven regional development processes between periphery and centre because factor endowments, like knowledge, are not evenly distributed in space. It is argued that this type of analysis is still valid today and particularly applies to newly industrialized countries (NIC) countries like Brazil (Santos et al. 2005).

Knowledge transfer in organizations is by many authors defined as: "The process through which one unit (e. g., group, department, division) is affected by the experience of another", (Argote and Ingram 2000). Knowledge transfer in organizations, like any other place in society, has to involve individuals. But knowledge transfer in companies also takes place between groups, departments and so on. Knowledge transfer is identified when there is change in behaviour. But if this change shall contribute to the improvement of the company's competitive situation, this change has to be measured in, for example, saved working hours.

Argote and Ingram (2000) referring to Walsh & Ungson, (1991) use five retention bins or repositories for knowledge in organizations:

(a) individual members
(b) roles and organizational structures
(c) the organization's standard operating procedures and practices
(d) its culture
(e) the physical structure of the workplace

Expressed in another way we can say that the above mentioned bins can be used as categories for the stock of knowledge in organizations. Developing this further one can say that knowledge is embedded in three basic elements of organizations (and the subnetworks between them) that include:

- members - the human component
- tools - the technological element defined broadly
- tasks - goals, intentions and purposes

In this article, I make reference to an ongoing project where we have developed and operationalized the concepts mentioned above to measure how the stock and flow of knowledge influences the competitive situation of a company.

3. Measuring knowledge with respect to competitiveness

Investigations which focus on how to measure what knowledge means for the competitiveness of the firm are of critical applied interest yet remain an area of research in which there have been few results. One of the best known efforts is a European Union initiative known as the MERITUM Project. The six countries participating in this program include Spain, France, Sweden, Finland, Norway and Denmark.

MERITUM: **ME**asu**R**ing **I**n**T**angibles to **U**nderstand and Improve Innovation **M**anagement

The conceptual point of departure for the MERITUM Project involves production inputs. When a company produces outputs, inputs can be divided into two categories:

- labour, capital and raw materials
- intangibles

In the accounts of the company, we look at:

- ordinary assets such as machines, buildings etc.
- financial assets
- intangible assets

One important aspect of the MERITUM Project effort was to find standards in which to measure intangible assets. This is important because companies need to measure and identify the level of knowledge used to increase their competitive situation. Thus, intangibles are defined as "non-monetary sources of probable future economic profits lacking physical substance, controlled (or at least influenced) by a firm as a result of previous events and transactions and may or may not be sold separately from other corporate assets." (Canibano 2004).

One result that has emerged from companies participating in the MERITUM Project was that the presence of a method to evaluate the value of intangible assets improved their ability to manage the development and use of knowledge. Another result from the project included clear rules about how to bring intangible assets into the ordinary bookkeeping. While bookkeeping was an interesting part of the project, it remains beyond the scope of work reported here. The focus here targets how the company can make its management more effective so that the generation and development of knowledge takes place in such a way that it actually improves the company's competitive position.

There is a need to clarify the two concepts 'intangibles' and 'intellectual capital'. While both refer to non-physical resources, 'intangibles' are, in most studies, linked to management and accounting while 'intellectual capital' is often used to analyse how the business community develops. In this article, I analyse 'intangibles' from the company's point of view and will leave out further discussions of 'intellectual capital'.

I analyze the situation in three phases to determine the value of intangible assets and knowledge capital (see definition in Section 3.1). These phases include:

Identification: knowledge in relation to the processes that are central for value creation in the company.

Measurement: a useful and operational set of indicators to measure what the knowledge capital actually consists of.

Management: development of a management system that incorporate the effect and relations that knowledge capital have on achieving the company's objectives, (usually maximization of profits).

For the company, it is crucial to make clear what core competencies are expected and how knowledge capital is related to these competencies. The company also needs to identify the networks in which this knowledge is distributed.

It is vital to clearly distinguish knowledge as a stock from knowledge as a flow. Namely:

Knowledge as a stock: a company must be able to identify what it has and can use.

Knowledge as a flow: a company must know how it can influence the creation and development of knowledge capital.

In general it would have been a good idea to have general criteria to measure both the stock and the flow of knowledge which would enable comparisons between companies. Results from the MERITUM Project have shown that it is not easy to develop general criteria because it is almost impossible to define the core competencies of a company without going more specifically into the actual production processes.

3.1 From intangible assets to knowledge capital

On an operational level the definition of knowledge capital can be presented in three forms as follows:

1. *Human capital:* Defined as the knowledge the employee has and uses in the operations of the company. Often specified as the employees' level of education and expertise in the company.
2. *Structural capital:* Defined as the knowledge that is left in the company when the employees have left (e.g. patent rights, company routines, databases, etc.).
3. *Relational capital:* Defined as all human capital and structural capital that linked in networks with all external relations the company has (e.g. contracts with other companies, market channels, etc.).

A definition commonly used is then:

The company's knowledge capital equals the total of human capital, structural capital and relational capital.

3.2 Collection of data for the analysis of knowledge as a part of the company's competitive situation

The MERITUM Project lists 15 indicators under the heading of human capital, 9 under structural capital and 6 under the heading of relational capital (Canibano 2000). This makes it possible to look at the guidelines from the MERITUM Project and relate them to the core competencies of companies. These indicators suggest what kind of knowledge capital the company has and the types of changes that take place when assessing:

- change in inputs of goods and services
- new capital equipment
- new relational or operational agreements with other companies
- new recruitment or new developments of labour with new qualifications
- development of new technologies
- new research and development operations
- new training programs for the labour force

Tacit knowledge will be a central concept in this connection and is important to study the codifying processes that take place when tacit worker knowledge is transferred to explicit knowledge for the company. The concept of tacit knowledge was first developed by Polanyi (1960) and has since subsequently become a central concept in the literature (Lundberg and Maskell 2000).

4. Aker Verdal as a case study

Aker Verdal is a company that produces equipment for the offshore sector. The North Sea has been their primary geographic market, but in recent years, Aker Verdal has produced equipment used in offshore applications in Canada and the Gulf of Mexico. Between 2000 and 2006, the company had a total annual production value of about $200 million USD. The main product from Aker Verdal includes steel jackets; a market which has recently experienced significant changes in demand. In 1999 there was a sharp downturn in orders and about 600 of the company's 1200 employees were temporarily or permanently without a job. In the year 2000 the market situation improved rapidly with orders between 2000 and 2005 deemed reasonably good and a new upturn taking place in 2005 orders. Currently, there is an anticipated downturn starting immediately (end of 2008).

In the problematic period of 1998-2000 the company had extensive educational programs for temporarily laid off employees. These programs have been evaluated as reasonably successful but there has been no extensive analysis of how these programs influenced the company's competitive situation. Given this background the central research questions from the standpoint of the company have been:

1. Which processes generate development of knowledge within the company?
2. How can we actually analyse and describe how knowledge leads to reduced costs and/or increased quality in production?
3. How does this development of knowledge (at Aker Verdal) spread into the business community of the surrounding region?

One of Aker Verdal's most important competitors in producing steel jackets for the offshore sector is a Spanish company named Dragados. Dragados has a wage structure that is roughly half the cost of Aker Verdal's. Yet Aker Verdal still wins contracts. This has led managers of Aker Verdal to conclude that competitiveness is related to a knowledge component of Aker Verdal's production process not found in the Dragados process. Thus, this case study research reported here forwards two primary objectives that include (1) analyzing the character and extent of this knowledge component and (2) develop strategies that focus on how the company can further improve its competitiveness with respect to this knowledge component.

4.1. Preliminary observations

Aker Verdal produces steel jackets for the off shore sector which are placed on the bottom of the North Sea to service production units on the surface. Aker Verdal started building the specific steel jacket focused on in this case study (called a Valhall and illustrated in Figure 1) in May 2008. The jacket is scheduled to be finished in July 2009, weighs about 7000 tons, has a cost of roughly 100 million USD, and takes about 500,000 work-hours to build. The project work on this specific Valhall can be divided into engineering and production. In this case study we concentrate on the production phase.

Previously, the company's knowledge capital was defined as consisting of human capital, structural capital and relational capital as graphically presented in Figure 2. This is the definition of knowledge capital used in this project.

Figure 1. Steel jacket produced by Aker Verdal for a North Sea application (illustrative photo of a similar project completed previously)

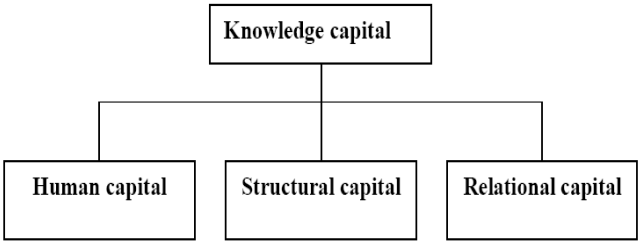

Figure 2. Definition of the company's knowledge capital.

The central conceptual unit in the planning and operational phase of producing the Valhall jacket is known as a **work package.** The production is divided into approximately 600 work packages and each work package has complete drawings of the "piece" that shall be produced and a description of all work processes including specific tasks (what will be done, e.g. welding technology), quality standards (e.g. which welding certificates workers are required to have for each specific "piece" and task), and estimated number of work hours.

The central characteristic of the data collection in the project is that knowledge capital is linked to the properties of each work package. This is done by using indicators for human capital, structural capital and relational capital. A number of indicators and their prioritization include the following:

1. Group size
2. Competence level (welding certificate)
3. Average age of persons in the group and average years of work experience in the firm
4. Participated in any training activities specially designed for this project
5. Welding technology
6. Ability to understand drawings
7. Preciseness of measuring steel structures (the work package)
8. Innovations taking place
9. Quality control procedures
10. Communicative skills
11. Collaboration with other departments of the firm
12. Collaboration with outside firms
13. Language problems

The examples above are just some of the indicators we use and they can be related to the following headlines: (1) Indicators relating to workers' competence, (2) Indicators related to technology and (3) indicators related to communication and communicative skills.

For every indicator we register values. Special attention is paid to situations where work hours are saved or lost compared to the standard calculation for the specific work package. This data provides the basis for explanatory regression models that can empirically estimate relationships between lost/saved work-hours and measures of knowledge (e.g. levels of core competencies).

The central function of how communication and knowledge transfer takes place in the production of the work packages includes the central position of group leaders as presented in Figure 3.

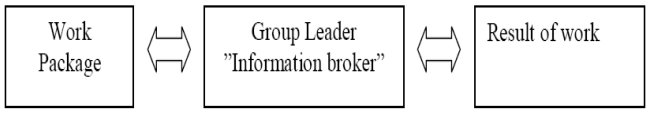

Figure 3. The central position of the Group leader as information broker

Work packages differ in size and content, from small jobs with less than 100 work-hours to large scale operations of more than 2000 work-hours. Two examples of job packages from the Valhall jacket assessed in the case study are presented in Table 1.

Table 1. Two examples of work packages from the Valhall jacket production.

Work No.	Name	Dept.	Total Work-hours
VRN6A1 5300-01	Valhall jacket - Install Lifting lugs section VR-A-150-30	A2	147.86
VRN5A3 5001-01	Valhall jacket - Prefabrication of mudmat for cluster section A-350 row A	A2	2 068.96

The central person in the production process is the group leader. The group leader receives all drawings and descriptions of the work package and organises and instructs the group of workers performing specific tasks. The first job presented in Table 1 involved the installation of lifting lugs and was performed by a group of six workers while the second job involving mudmat prefabrication was done by a group of twelve workers. The group leader "translated" all technical and organisational information to the group performing the tasks and has a central position as an information broker.

Data collection was based on interviews with the responsible group leader matched with additional data compiled for each work package. By November 2008, data were collected for about 300 work packages. Results thus far suggest that the ability of group leaders to perform their key roles as information brokers is vital for overall productivity. These results are consistent with the findings of others (e.g. Gourlay 2004; 2006) who discuss the central role of transforming tacit to explicit knowledge. Preliminary results from this case study suggest an ability to indirectly measure how the communicative skills of the group leader can stimulate the process of transforming tacit to explicit knowledge and thereby enhancing productivity.

4.2. Innovations in traditional manufacturing: Indoor building of jacket components

To enhance the effectiveness of production processes and to work independently of variations in weather, Aker Verdal builds many of the important and resource consuming parts of the jacket indoors. To do this, the company had to build up indoor construction facilities (scaffolds) to allow workers access in performing needed welding operations. This proved costly and time-consuming and the company considered changing to indoor mobile lifts or other forms of mobile platforms that could put the worker in the right position to do the required welding tasks.

A team was put together with workers from the company (welders) and engineers. This team contacted different producers of mobile lifts and platforms and resulted in a new mobile platform being introduced and used in production. A crucial phase of this development was how to identify the workers' tacit knowledge about how things could be done and recode this tacit knowledge to explicit knowledge in cooperation with a producer of mobile lifts and platforms.

Using Schumpeter's definition (Schumpeter 1943), this could be labelled as process innovation. One can argue the extent to which change occurs prior to using the concept of innovation for a cost saving change in the production process and if this example fulfils the criteria. This said, the interesting aspect involves how the company manages knowledge processes and creates an innovative milieu for knowledge transfers; an element that is likewise addressed in Cavusgil et al. (2003).

5. Summary and conclusions

In this article, I adapt and extend MERITUM Project objectives that seek standards upon which to measure intangible assets. This is done using a case study approach of a firm engaged in the production of steel jackets for the offshore oil industry in peripheral Norway. This case study provides a framework for analyzing how the creation, use, and transfer of knowledge are linked to the performance and competitiveness of the firm. The importance of knowledge to explain firm performance and competitiveness is reflected in a growing number of theoretical and policy oriented articles. The work described in this article provides an empirical contribution based on case study research.

In developing an approach that links knowledge and competitiveness, the building blocks from the MERITUM Project provide useful starting points. It is

also important to note that the organization of production in the company is crucial for useful empirical assessments. Without the descriptions, calculations and drawings forming the work packages, it would have been difficult to make reasonably reliable estimations of the connections between (1) knowledge and communicative abilities and (2) productivity.

In the literature about measurement of intangibles (e.g. Sveiby 1997 and Bounfour 2003), there exists clear statements that there is not a single unique method of evaluation and measurement of intangibles. The same seems to be the case for the analysis of knowledge and communicative abilities at the firm level. We cannot expect to find one single method of analyzing the link between knowledge and competitiveness.

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