The Value of Knowledge Networks: Conceptual Framework in Application to Sustainable Production

by

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ABSTRACT

The thesis is motivated by two major trends: the rise of a global information and knowledge economy, and environmental degradation and the search for sustainable solutions. The increasing importance of knowledge has by some been equated with a new industrial revolution, one based on computer technology, digital infrastructure, and highly educated and technically skilled workers. But how do we assess the value of knowledge in this 'new' economy? The question over value is explored through the diffusion and localization of new knowledge via a knowledge network, based on information technology. The central argument is that in the knowledge economy, the value of knowledge lies in the ability to share it over a knowledge network, which allows for diffusion and localization of new knowledge.

This central thesis and the value of knowledge networks is further explored by looking at the case of environmentally friendly or sustainable production. The knowledge network targets barriers to environmentally friendly practices by encouraging and enabling diffusion of knowledge related to sustainable products and processes. The knowledge scope for environmental solutions is analyzed, with the objective to develop common categories, and to understand better the increasing complexities and knowledge needs as enterprises engage in sustainable production.

In discussing the knowledge economy and knowledge networks, the thesis focuses mostly on the business enterprise. But the development of the knowledge age has much larger implications, such as 'knowledge for whom?' and 'value for whom?'. The information technologies and networks offer new ways for people and groups to interact and influence social issues and can enable the diffusion of wide variety of views and perspectives. Thinking about the information and knowledge age in the larger economic and social context requires us to consider who builds, controls, influences and benefits from the technology and its use. Before we can reasonably approach this analysis, a basic conceptual framework or understanding of knowledge sharing, knowledge networks, and value of knowledge is called for. This thesis is a building block for such a framework, a contribution to future research into the economic and social implications of the knowledge economy.

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Chapter I: Introduction

The phenomenal rise in the importance of knowledge in the economy is heralded by some as a new industrial revolution, one based on computer technology, digital infrastructure, and highly educated and technically skilled workers.[1] And while at first the spotlight rested mainly on productivity gains due to the application of information technology, soon after the concept of knowledge received increasing attention. In business terms, knowledge is an asset to be managed, nurtured and retained. In economic terms, knowledge has seized to be a residual of technology in the production function and can rightly be claimed as a factor of production.

But how do we assess the value of knowledge in this 'new' economy? The question over value is explored through the diffusion and localization of new knowledge via a knowledge network, based on information technology. The central argument is that in the knowledge economy, the value of knowledge lies in the ability to share it over a *knowledge network*, which allows for *diffusion* and *localization* of new knowledge.

This central thesis is further explored by looking at the case of environmentally friendly or sustainable production. Information and knowledge networking is increasingly being viewed as an essential module in the solution to environmental problems.[2] The environmental dimension is an integral part to the operation of firms, given regulation, standards, organizations, consumer demands, and scientific discoveries, at both the local

[1] This revolution has been variously referred to as the "new economy," "Information Age," or "knowledge economy."

[2] Choucri (1999); Richards and Kabjian (1997); Shaft et al (1997); Eagan et al (1997).

and global level. Effective knowledge management and networking form an essential part of the solution strategy for integrating environmental factors into corporate operations.

Hence, the thesis is motivated by two major trends: the rise of a global information and knowledge economy, and environmental degradation and the search for sustainable solutions. The impetus is to understand the possible contribution the knowledge economy can make to environmental issues; in this case the development of knowledge networks for sustainable production. The knowledge network targets barriers to environmentally friendly practices by encouraging and enabling diffusion of knowledge related to environmental problems and solutions, such as sustainable products and processes.

The first chapter compares the industrial revolution and the new knowledge economy, to examine whether the latter signals a fundamental shift in economic structures, from manufacturing to knowledge-based services and high technology sectors, where production of ideas, or knowledge, reigns. Although still in its early stages, the knowledge economy changes labor markets and business organization, as well as what constitutes value in the economy.

The next chapter discusses the value of knowledge. Knowledge can no longer be ignored as a residual in the production function. Rather, it has crystallized into a factor of production. This indicates that it might be treated as a commodity, shared and sold. This means we have to think about knowledge value not just as an asset at the local level, but at a level which includes diffusion and localization of new knowledge. Central to such a process is a knowledge network, built on information technology. The transfer of knowledge over a network faces boundaries of varying complexity, depending on how embedded the knowledge is in local communities and how easily it can be represented by common language and categories.

The next two chapters consider the concepts of knowledge networks in terms of environmentally sustainable production. The first introduces some environmental imperatives for firms and looks at two solution strategies, life cycle and environmental management systems, to demonstrate the rising complexities and knowledge needs. The final chapter charts the knowledge scope for environmental solutions, with the objective is to develop common categories for knowledge analysis, and to understand better the increasing complexities and information/knowledge needs as enterprises engage in sustainable production. Through this we can identify critical areas or processes for enterprises that seek to learn from each other through sharing of some sort in the domain of sustainable production.

Chapter 2: Economic Revolutions and the Knowledge Economy

2.1 Industrial Revolution

Both the agrarian revolution and the industrial revolution mark transition to new epochs in history which brought fundamental changes in the way people organized their work and communities. During the Neolithic revolution, people largely shifted from nomadic hunting-and-gathering lifestyle to settled communities and farming. The industrial revolution pulled people out of the agricultural settings into cities, from farming and handicraft work into factories and manufacturing. Both revolution were founded on changing technological knowledge and deeply affected productivity and economic surplus and hence the number of people the economy could support (Stearns, 1993; Landes, 1969).

The industrial revolution had three central features: first, machine power and mechanical devices were to a large extent substituted for human strength and skills; second, industrial organization (including habitation) changed as manufacturing required concentrated workforce around factories, with new responsibilities, roles, and skills; and third, the industrial transition brought about a cumulative and continuous technological and scientific advancements.[3]

Innovations in one field depended on advancements in others and, coupled with the constant push for technological development, set in motion a reinforcing process of technological change. As Landes (1969) put it, "change begat change," (p. 2). This feature stands in contrast to prior centuries of sporadic innovations in the West and reflects the rise of rational drive for mastery over people's environment. The trend rested on the growing ability to measure, manipulate and apply natural forces and human creations.

Industrialization had pervasive economic and social impact, perhaps the most obvious in the way people worked and where they lived. It also brought on changes in markets, such as financial, raw materials and consumer items, and it required new business organization and functions (i.e. research and development, marketing). When viewed as a foundation for the modern economy, the industrial revolution also called for new government functions, more extensive distribution and transportation, a more developed credit structure, and expansion of education (Landes, 1969).

The transition to industrial economy took time to unfold – it is not a clearly demarked point in history. Steam power was introduced to factories in England in 1780s, but the diffusion of this technology was not uniform. Industries such as cottons spinning mechanized rapidly but the economy on the whole changed slower. The shift from rural work to urban was well under way by the 1850s, but even then there were still as many rural dwellers as urban and as many craft workers as factory workers (Stearns, 1993). "Industrial revolutions take time, and they involve different parts of the labor force in quite different degrees of change," (p. 9).

So while we can't assign clear boundaries to the Industrial Revolution, we can define it as a series of processes which in the larger scheme provide a clear break from the agrarian culture that went before. The main features or processes that stand out are: first, machine power replaces human strength; second, organization of industry and, to a

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[3] Based on Landes (1969) and McPherson (1994).

large extent, society; and third, the industrial transition brought about a cumulative and continuous technological and scientific advancements.

2.2 The Information Age and Knowledge Economy

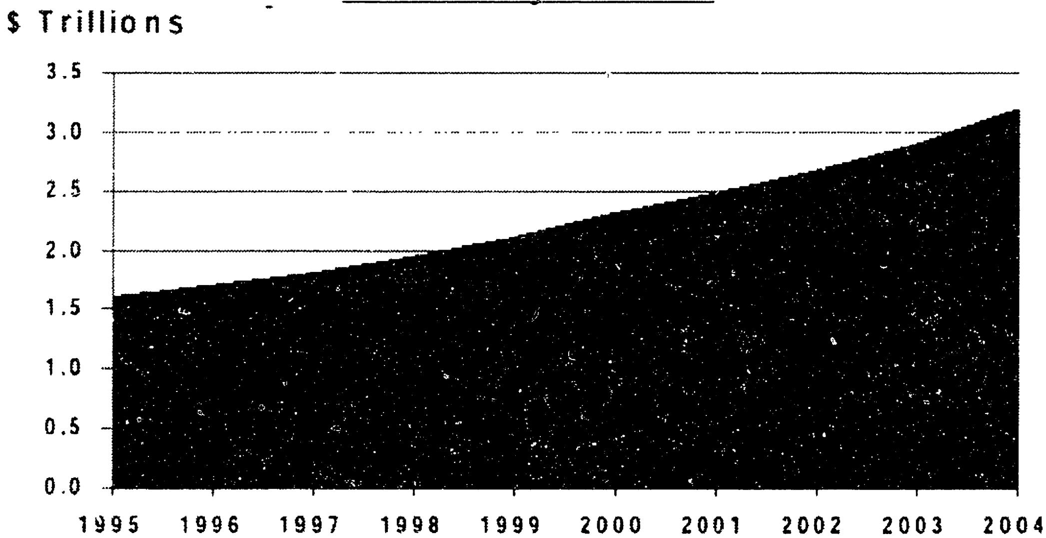
As with the industrial revolution, a cumulative transformation of economic organization is now seen to be taking place, with information and knowledge being the central foci in industrial organization. The term ‘knowledge economy’ refers to a fundamental shift from manufactured-based economies to service-based economies, of a certain type. While the term ‘service’ includes banking, communication, education, entertainment, and transportation sectors, as well as high technology sectors, the knowledge economy is based primarily on the latter, with technological breakthroughs changing the character and scope of knowledge production. In the knowledge economy, the production of ideas, not goods, drives growth, and information and telecommunication technologies support and enable this development[4]. The era of computer and information technology, i.e. the Information Age[5], and the 'knowledge economy' are thus inextricably intertwined.

The infrastructure technology serves as the necessary conduit for ideas and hence must be viewed as the essential backbone of the knowledge economy. Know-how, research results, drawings plans and all sorts of data, information and knowledge can be almost instantaneously shared across the globe. The 1999 UNDP Human Development report states that the “fusion of computing and communications – especially through the

[4] See for instance Neef (1998).

internet – has broken the bounds of cost, time and distance, launching an era of global information networking, "(p. 57). These new technologies, to a large extent, drive globalization, making it possible for firms to find new markets and new production resources. They also enable less developed countries to start knowledge production and find a fast track to growth by building local capacity and skills (UNDP, 1999).

Figure 1
Information and Communication Technology Industry:
Actual and Projected Growth



(Source: Digital Planet 2000: The Global Information Economy)

Approximately 85 percent of Americans work in services. This includes lower-paying jobs, such as fast food work, but estimates suggests that perhaps as much as 65

[5] The Information Age refers to the diffusion and application of computer and information technology throughout society, and includes the notion that we can capture, represent or codify things around us as bits of information.

percent of the new service workers fall in the 'high' skill area. High technology sectors and highly skilled professionals mark the service or knowledge-based economy.[6]

However, the knowledge economy is not limited to service and high technology companies. Information technology and knowledge-based solutions have made extensive inroads into manufacturing and will continue to do so. They enhance both products and processes and marketing and sales: features can be enhanced to differentiate the product, processes and value-chain operations can be linked and managed better, marketing and financial data is easily shared across the world, and electronic commerce over the internet adds another venue for reaching customers.

But is the growth of high-technology and knowledge-intensive sectors akin to a industrial revolution? Answering this question will invariably involve speculation because the information and knowledge economy is still young and the concepts still in its inception. But we can approach these questions by briefly superimposing the main features of the industrial revolution on the information/knowledge economy.

First, as with machines replacing human skills and efforts, are computers and information technology having similar far-reaching effects? Certainly this field is rife with futurologist speculation, but computer technology is in fact aimed at making work easier and more effective. The 'killer application' that ignited the diffusion of computers was the spreadsheet software. Although it does not replace accounting skills, it made the work quicker, easier and less error prone.

Perhaps the change in composition of the employment market is a better indicator, with fewer and fewer people working in manufacturing. It mimics the somewhat gradual

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[6] See Neef (1998) and Wyckoff (1996).

move from agriculture and craft to manufacturing in the 1800s. Those who have little or no technical training and computer knowledge are increasingly feeling marginalized in the economy.

Second, will the information/knowledge economy lead to large-scale transformation of industrial organization? For the workers, this does not seem to be the case. People are hardly likely to move out of cities for the foreseeable future. And if we count urban sprawl as a significant habitation change, it is not a phenomena caused by the knowledge economy.

The change, however, might be much more significant for companies. Globalization is aided by IT technology, and knowledge-based industries (such as software development) are not as limited by geography as traditional industries. The knowledge economy for businesses includes e-commerce, global networking, extended enterprises, and even knowledge commerce - where knowledge of one company can be packaged, bought and sold. Although these may not amount to the same jump as took place during the industrial revolution, coupled with globalization and shift into high technology services, the effects could be transformative. And if the company is purely a service or knowledge-based one, its structure may shatter the traditional business mold.

And third, is this a start of a different scientific and innovative process, with a vastly different growth trajectory? The characterization of this process in the pre-industrial versus industrial has been dichotomous – before there was only sporadic innovation, while after there was a reinforcing, cumulative development. It is then hard to describe the current phase as something yet different. But if we consider that the industrial age also depended on communication of experience, on transmission of information and knowledge, the information age may have something new in store. It is an era where we intensify the codifying and collection of information and knowledge from our surroundings, where eventually "all information about physical objects, including humans, buildings, processes and organizations, will be online."[7] The world can then presumably be represented in bits of information and our interactions with it immensely enhanced given enough processing power.

If we are witnessing a revolution it is still in its infancy. The new economy, or knowledge economy, will develop as a complex system, with reinforcing events that can lead to great leaps and exponential changes. What is already evident is a process of dematerialization (Coyle, 1998). The knowledge economy is largely based on the growth of service industries, not manufacturing. The ratio between physical and non-physical products changes and the value in the economy has less and less physical mass. This does not mean that size of manufactured output will be reduced absolutely; rather, it's proportion of economic activity is falling in relation to services, especially information and knowledge-based sectors.[8]

In short, the hallmark of the industrial revolution was a new organization of labor and capital in industrial clusters, augmented by technological advancements. It brought

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[7] Brown and Duguid, 2000, pp. 15.

[8] In our context, dematerialization can be represented in two ways. First, the ratio between physical and non-physical products changes and the value in the economy has less and less physical mass. "Whether it is software code, genetic codes, the creative content of a film or piece of music, the design of a new pair of sunglasses or the vigilance of a security guard or helpfulness of a shop assistant, value is no longer in three-dimensional objects in space,"(Coyle, 1998, p. xii). And second, with information and computer technology as well as knowledge management of some sort, companies can produce more efficiently or in different ways. This might be especially important in terms of environmental management. The information/knowledge technologies will be integral

about massive gains in production, both in terms of size of output and the variety of things produced . As for the knowledge economy, the crucial economic variable is just that, knowledge, supported by information technology. Instead of marking a new period of greater materialization, it heralds a shift to an economy of less physical mass, one of dematerialization. But what then is the value-added in this economy?

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to reducing material consumption, through better choices, more informed decisions, and re-use and recycle systems which require coordination and information flows.

Chapter 3: Knowledge Networks and the Value of Knowledge

In the traditional economy, value is relatively clear because inputs and outputs can be measured. For early economists labor, land and, later, capital determined value. The idea of technology as a factor of production emerged in a systematic manner in the middle of the last century, but formally it has been treated as a black box – an exogenous variable.[9] In this sense, knowledge is a residual in the production function.

With the advent of the information and knowledge economy, knowledge has taken on increasing importance as a factor of production[10]. As such, knowledge is an asset and should be managed within the organization to improve production.[11] But at the same time, viewing knowledge as a factor also indicates that it can be acquired from outside the organization and applied within; that is, it can be shared and sold as a commodity.[12] This means that we have to think about value not just as an asset at the

[9] According to Bontis (1999) neoclassical economics still treat knowledge with indifference: "Firms are assumed to have the same fixed knowledge as they are jockeyed around by the invisible hand of the market," (pp. 438).

[10] Arrows (1999).

[11] The literature on intellectual capital views 'intangible assets' such as organizational knowledge as crux of competitiveness. Based on Kogut and Zander's (1992) work, Bontis (1999) identifies three sub-domains of intellectual capital: human capital - the tacit knowledge embedded in the minds of employees; structural capital - the organizational routines of business; and, relational capital - the knowledge embedded in relationships established with the outside environment (pp. 443-44).

[12] Writing about knowledge *within organizations*, Prusak and Cohen (1998) maintain that knowledge is exchanged, bought, bartered, found, and generated. This means that there is market for knowledge in organizations, with buyers, sellers, and brokers. The buyers are seeking solutions for complex or uncertain issues; the sellers have knowledge about a process or subject, recognized through internal market reputation. The brokers make connections between buyers and sellers - they like to understand the organization and they know where to go knowledge. The knowledge markets have a price system, mostly based on reciprocity, reputation, and altruism (pp. 143).

local level, but at a level which includes local transfer of knowledge to the global/general and back to local or user level.

3.1 Information in the Public Sphere

In 1962, Arrows argued that while it was costly to produce scientific or technical knowledge, transferring this knowledge was next to free. And since one firm could consume this knowledge without reducing the ability of another to do the same, knowledge was perceived as a public good. This argument applied particularly well to basic research, which is only used as informational input into other inventions. If a private organization could not appropriate the returns from its investment in basic knowledge creation, new knowledge would be underprovided.[13]

Similarly, once information is transmitted it can be reproduced almost without cost. If you look at information as a public good, it is valuable only to the users. But not in the sense they will pay for it, since it is available basically for free. All the property rights are in the public sphere and the provider does not appropriate anything from the creation of the information. Furthermore, once information is looked at, it may not have much value to the recipient. How do you know if what you buy is useful until you look at it? And once you look at it, you incorporate the content and the information loses its value (Varian and Shapiro, 1999). This assumes that information, or knowledge, is easily appropriated or assimilated.

[13] Arrows, 1962; see also Mowery and Rosenberg, 1989, and Dosi, 1998.

Following Arrow's argument, other scholars pointed out that utilizing scientific and technical information was a costly process and often knowledge intensive itself. [14] Having information does not mean you can act on it or somehow implement it. And knowledge may be very difficult to codify and transmit as information for others to peruse. Knowledge is captured locally in organization, people, processes, data, text, and so forth. It may not easily cross boundaries between different users, such as firms or organizations.

Knowledge boundaries exist between different groups, functions, or individuals. Knowledge is not independent of it's context, ready to be extracted and transferred between different entities; rather, it is localized and embedded to a greater or lesser degree in a practice and may be hard to communicate across to another practice (Carlile, 2000; Brown and Duguid, 2000).

3.3 Knowledge Boundaries and Knowledge Transfer

The ease or difficulty with which knowledge is transferred is in many ways captured in the difference between information and knowledge. First, "knowledge usually entails a knower," (Brown and Duguid, 2000, p. 119). That is, knowledge is usually associated with people, someone who holds it; 2) information is mostly seen as a self-contained substance and is thus easier to detach than knowledge; and 3) knowledge seems to require assimilation. People have to digest it, to understand and commit to it.[15]

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[14] Mowery and Rosenberg, 1989.

[15] Based on Brown and Duguid (2000). Foray and Lundvall (1998) identify four different kinds of knowledge: 'know what', 'know why', 'know how', and 'know who'. Authors differentiate between tacit and codified knowledge. Tacit is contained within its

Carlile (2000) offers three modes of thinking about how knowledge is moved across boundaries.[16] The first one, *transfer mode* has its foundations in information theory and takes a syntactical view of knowledge and information. Moving information in this case is a matter of information processing. If entities share a syntax or categories and have adequate processing capacity, then knowledge can be transmitted. The problem is that syntax can change, it is not shared across boundaries, and categories may not be known (p. 7).

Translation mode recognizes that communication can be problematic because knowledge does not mean the same thing to all people and doesn't necessarily serve the same purpose. In other words, knowledge categories are different or ambiguous - they have different semantics. To overcome these boundaries, categories need to be translated for common interpretation. But this mode falls short of answering why these differences exists. Are they "just different interpretations or are they more concretely but dependent results that are at odds with each other?" (p. 10) and thus have practical implications.

To address these concerns, a third mode is proposed, the one of *transformation*. This view takes into account pragmatic boundaries between communities of practice. The locality shares understanding and categories and has invested the knowledge in certain purposes and ends. These pragmatic issues may be at odds with other groups and be dependent on each other.[17] Differences go beyond the syntactic and semantic; to share,

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possessor and is not easily transmittable. Codified knowledge has been processed and systematized so that it can be easily communicated.

[16] Carlile builds his argument in the context of new product development but it has far wider applicability.

[17] Carlile describes dependencies and differences through a case study of product development in a large automotive firm. Different groups of stylist and engineers have critical input into the development of a car. The design people want a particular look and

communities have to devise a shared method, specify their differences and dependencies, and then alter boundaries through transformation of knowledge and iteration (p. 19).

3.4 Knowledge Networks: Diffusion and Localization of Knowledge

Given the increased realization of knowledge as a factor of production and our understanding that knowledge may not move easily, knowledge takes on value when it can be transmitted, from the local level to a general level and back to local. Instead of focusing on knowledge as having characteristics of a public good and it's value hinging on how it can be kept from escaping from the local setting (minimizing the public property), the value of the knowledge economy is seen as lying in the diffusion and localization of knowledge.

Figure 2
Diffusion of Knowledge

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aesthetic features, the engine group has power and fuel consumption requirements, the safety people have to address collision concerns, and so forth. Each group is specialized, focusing on particular features, and may have solutions that function well within their domain. But decisions in one area affect other areas, sometimes in ways that will not be evident until in later stages. This can result in expensive delays and rework if not accounted for in the beginning. Carlile observed that established ways of communicating design and decisions, through clay models and drawings, were limited and rigid and did not represent all the knowledge dimensions needed for early stages. "What was missing was a tool that provided a common ground where the team members could see the relevant impact of the differences and dependencies on each other," (p. 33).

Figure 2 represents a process where the local entity transfers knowledge to a general level where it is available for diffusion. Diffusion will occur when others interact with this knowledge. And if others can use the same categories within their boundaries, the knowledge becomes *valuable* to them.

A knowledge network is essential to such a process. Choucri and Millman (from Choucri, 2000) define knowledge network as:

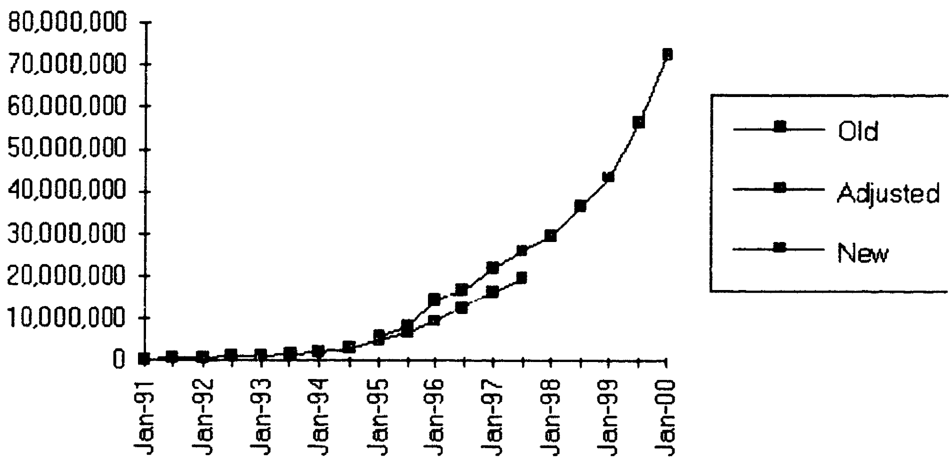
> A computer assisted organized system of discrete actors, with a) knowledge producing capacity, b) combined via common organizing principles, c) retaining their individual autonomy, such that d) networking enhances the value of knowledge to the actors and e) knowledge is further expanded.

To be successful, the network has to address collection, organization, presentation, and communication of knowledge in such a way that it will expand the boundaries of 'communities of practice'. It may not replace local knowledge communities, where personal contact and shared understanding matter most, but it should enable the diffusion of knowledge by stretching or interconnecting these groups. And it has the further potential to expand the knowledge base due to network interaction.

On the surface, network connectivity is limited only by communication infrastructure – roads, transportation, telephone lines, cable services, or wireless access. Postal services are a form of a global network as they facilitate person-to-person communication all over the world. But what the posted letter accomplishes in a few days or weeks, a telephone conversation will do in a matter of seconds. The telephone adds value by eliminating time lags and also by allowing for spontaneous interaction not possible through the mail. Phone communication differs mainly in time and form (spoken versus written) but possibly also in content.

The Internet breaks away in form and content. It arrives in the wake of the computer invasion. The potential applications of the computer are of course still developing but it is now the main tool for information storage and management. This information can now easily be passed around the world and made accessible through a variety of interfaces. Person-to-person communication can also take place via the computer, in either written or spoken language. Digital technology has made the network 'a place'; in a simplified sense, information is stored there, people meet there, and they shop there.

Figure 3
Growth of the Internet: Domain Host Count



Notes: The old survey counted the number of domain names that had IP addresses assigned to them. The new domain survey is the reverse of the old survey. It counts the number of IP addresses that have been assigned a name.

(Source: Internet Software Consortium (www.isc.org).)

The ubiquitous Internet is fundamentally about transmitting data or information. It then appears as a perfect venue for trading information and knowledge. The problem is of course how to value information and whether people are willing to buy 'digital' content over the Internet. So far, the Internet operates within syntactic knowledge boundaries, displaying information that can be readily scanned through and its usefulness quickly assessed. Sooner rather than later the development of the knowledge economy will need the means to deal with more difficult boundaries than syntactic ones. To analyze the role of knowledge networks in this context, a distinction should be drawn between connectivity, tools and contents.

3.5 Connectivity, Tools and Contents: the capacity to share knowledge

A knowledge network consists of three essential elements: connectivity, tools, and contents. While technologies of connectivity form a basis for the knowledge network, the content of networks must be considered in order for these networks and various Internet services to flourish.[18] Sitting between the connectivity and contents are the tools – the interfaces and applications that can bring information and knowledge to the network, turn data or information of the syntactic kind into valuable content, and bring knowledge to the global sphere in such a way it can be localized again. As such, the tools represent the capacity to use connectivity and contents in a knowledge network.[19]

All three elements are interconnected, or overlapping. The extend and type of connectivity influences what content can be offered and imposes limitations on development of tools. The tools in turn determine content to a large extent; in other

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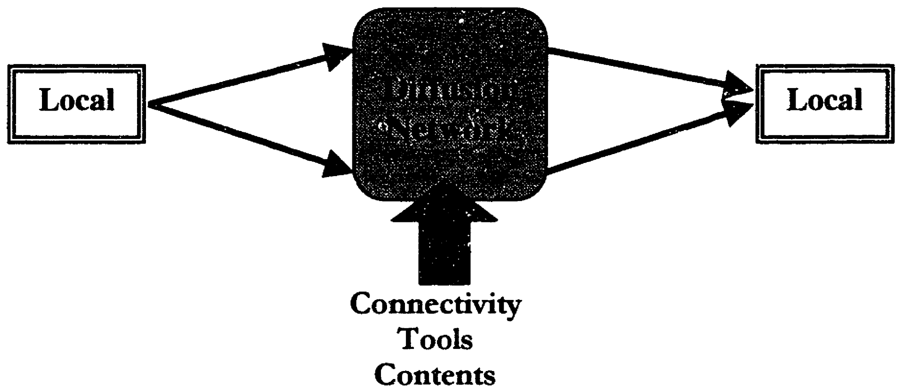
[18] Kirkman (1999) points out that the real power of information and communication technologies (ICTs) lies in the way they are used for social and economic benefit. It's more than being connected - the application and contents have to be considered. In development terms, Kirkman recommends three basic areas: commerce, education, and health.

words, providing certain type of knowledge or content calls for certain 'solutions' both in terms of tools and connectivity.

Figure 4
Basic Elements of Knowledge Networks



Connectivity comes from telecommunication lines, computer modules (PC's or other computer devices), and basic software for computer-to-computer communication (such as Internet browsers and network software). A step up from connectivity are the tools for communication – special software packages or graphical interfaces that allow information be manipulated or presented over the Internet. The Acrobate pdf format and the software package that handles it is one such tool. Database software has also been developed with the Internet in mind. This is in fact one of the most, if not the most, important application for the Internet. Data can now be accessed from almost anywhere. And these packages will automatically format and display database content for Internet

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[19] In her discussion of global knowledge systems, Choucri (2000) identifies three basic assets for electronic commerce and knowledge markets: physical connectivity, content provision, and management capacity.

browsers. The internal computer network in a company is now defined by access security, not physical location.

So while the database software is the essential tool for information transmission, the content has now become globally accessible. For the industrialized world, connectivity will no longer be the main issue. The questions will be what information is available, how is it organized, and how it is presented. Certainly technological issues dictate content to large extent, but as the speed of data transmission increasing, resource-intensive communication, such as video, becomes less restricted. A growing focus is on the content available and of what use and value it can be. For instance, is electronic book publishing a viable option? Will people pay for access to news services or information databases? And how can you put value on information and charge for it? How can someone organize and display their information or knowledge so that people will find it useful and valuable?

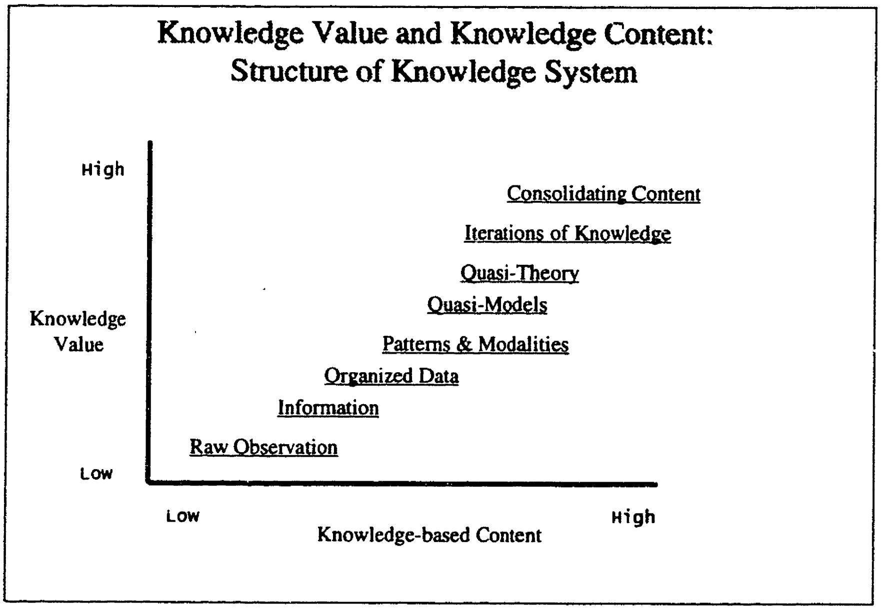
3.6 Network Effects and Increasing Returns to Information

Given the right infrastructure, connectivity and tools, and of course contents, we get a better sense of the value of knowledge. The value stems from the increased ability to share knowledge, which allows for pooling and trading knowledge. For instance, if sharing takes place, your knowledge may become valuable to others and you can extract value from it as a commodity. Furthermore, the ability to share means that knowledge can be pooled for greater effectiveness as input into further knowledge creation, which again might get pooled, hence leading to a virtuous cycle of knowledge creation.

And while other resources face decreasing returns, there are increasing returns to information. Adding more workers to machine will lead to decreasing returns from each worker as the machine output reaches its limit. But information can be used again and again. Several people can use a software package without decreasing its returns. And in fact, as more and more people use a software application, it can become even more valuable since now people have a standard and can share their work more easily.

In general, the increased processing of data and information should generate more value since more knowledge has been applied and more knowledge generated. Choucri (1998) proposes a spectrum of knowledge-based content, from low content to high, that forms a knowledge system. This spectrum of observations and analysis ranges from *raw observations* to *consolidating content*. In the proposed knowledge system, each step builds on the other and quality control is maintained, "so that 'better' knowledge is created, utilized, and disseminated," (p. 5). The goal of a knowledge network would ultimately be to move up the knowledge intensity and the knowledge value scale.

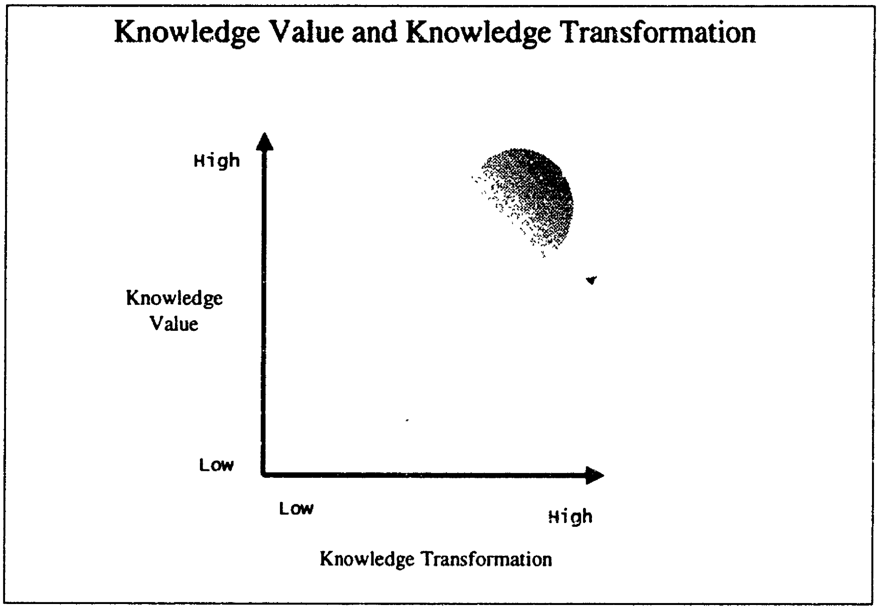
Figure 5



Source: Choucri (1998)

Another important dimension of value-creation of a knowledge network is the ability to transfer knowledge across stronger or more difficult boundaries. Based on the Figure 5, knowledge networks should also move along the transformation axis (from simple syntactic information to pragmatic knowledge), as diffusion and adoption of knowledge depend on it.

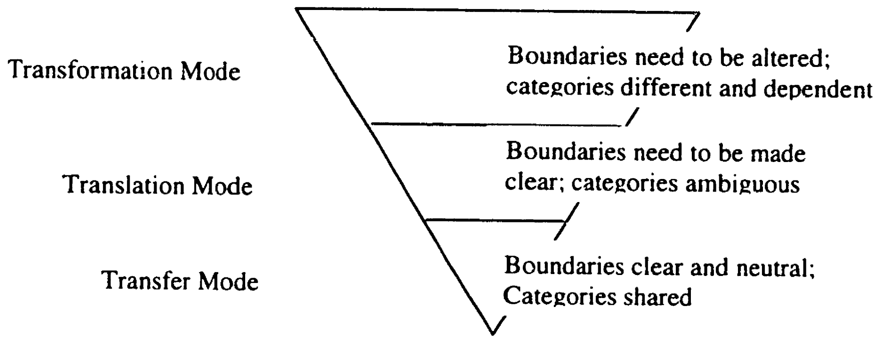
Figure 6



The 'Knowledge Transformation' axis corresponds to sequence of increasingly problematic knowledge boundaries - moving from those that are less clear, to those that need to be defined, to unsettled and contested ones, and those that need be changed (Carlile, 2000, p. 21-22). Carlile represents this order as a pyramid of modes, which are interdependent. As you move the pyramid, more and more effort (from low to high effort in Figure 5) is required to deal with knowledge boundaries, but there is also potentially greater value added[20] as you overcome those difficulties.

[20] In the context of knowledge networks, value-added of knowledge is meant here in the distributed sense, through increased diffusion and localization of new knowledge.

<u>Figure 7</u>
<u>Knowledge Boundary Modes</u>



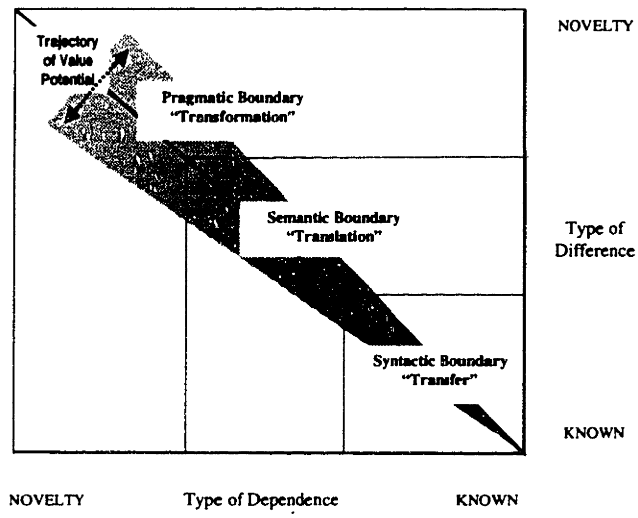
(Source: Adapted from Carlile, 2000, p. 22.)

Figure 8 merges the dimensions of potential value and boundary modes.[21] When differences and dependencies are known between different knowledge holders, then established syntax will suffice in overcoming boundaries. But as the novelty of dependencies and differences increase, the old syntax seizes to be adequate and another mode is called for. The third axes is the value potential of knowledge as more challenging boundaries are overcome.

[21] Adapted from conversation with Carlile, June 2000, and based on a draft document "Some Thoughts on the Deep Structure of Competitive Advantage Over Time," by Carlile.

Figure 8

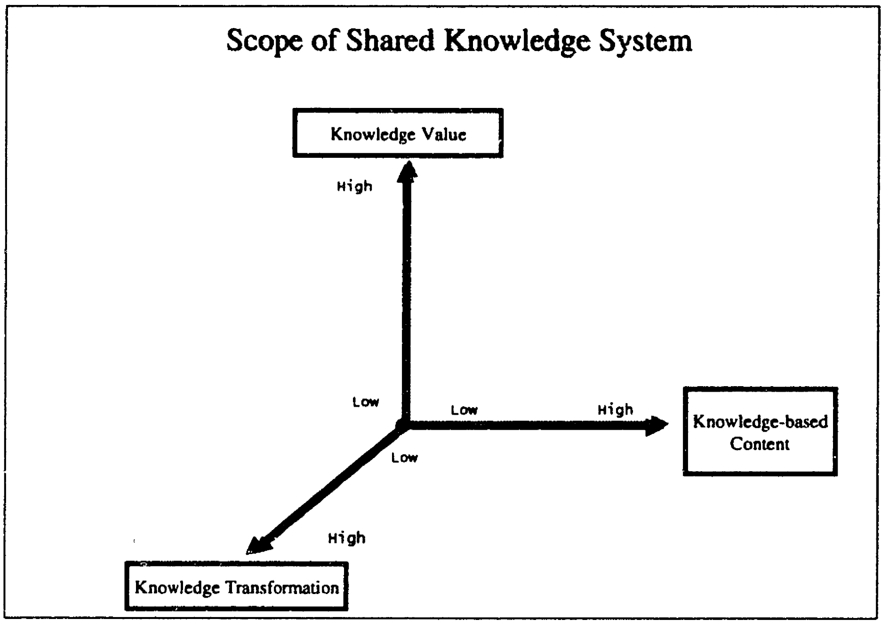
Knowledge Boundaries and Trajectory of Knowledge Value Potential



Source: Adapted from Carlile, 2000b.

The Knowledge Value, Content, and Transformation axis form the scope of a shared knowledge system - the dimensions which knowledge networks address through better connectivity, tools, and contents. More and more knowledge is then brought to the arena where it can benefit from network effects and increasing returns. In this sense, the growing connectivity and the creation of new tools and contents have the potential to increase the value of knowledge. The situation can also be viewed from the angle of value-added of knowledge. The increased recognition of the value of knowledge drives the level of knowledge intensity and changes in knowledge boundaries. There is more demand and need for solutions. Put together, these forces of the knowledge economy have reinforcing dynamics.

Figure 9



The ideas presented here are at an abstract level and still in their inception. To see how they might apply and where they might be useful, the following chapter focuses on knowledge networks for environmental, or sustainable, production. The application of information and knowledge technologies to environmental issues has been receiving increasing attention as a catalyst for reducing impacts on the environment.[22]

[22] Agenda 21, an international effort to accelerate sustainable development in developing countries, identified the lack of access to scientific and technical information as a serious barrier to implementation of environmentally sound technologies (ESTs) (see "Expert Meeting on Information Systems Related to Environmentally Sound Technologies," *United Nations Environment Programme: Industry and Environment*, 36-28 May, 1997.; Richards and Kabjian (1997) basis is that good decisionmaking draws on data, information and knowledge. Environmental improvement in the last decades has been driven by learning and application of knowledge. This process has generated data and new knowledge, which have been captured in various media, such as books and manuals. So "given the rapid advances in information technology, the quest is for more effective management and use of this information and knowledge," (pp. 7).; For Eagan, Wiese and Liebel (1997) "aggregated information is essential for linkages between human activities and the environmental condition, (pp. 3). To shift to a new industrial framework, in this case ecologically focused, capabilities for aggregation, evaluation, and

Legitimate pursuit of economic activity and business transactions has environmental consequences. Industrial production generates effluents, transmits pollution, and uses energy and other resources. Large corporations account for most of the world's economic activity and hence are the major environmental actors. But they are also innovators and agents of technological change, and combined with their environmental impacts, this makes them an integral part of the sustainability solution (Choucri, 1993).

It still leaves the question of how far firms should go to address environmental factors. For instance, are the products/processes designed with the whole product life in mind (product stewardship) or are only minimum standards applied (i.e. process emissions)? Do the products/processes take into account various levels of regulation (extended market) or do they mainly deal with internally developed solutions to a particular environmental problem, such as local effluence pollution? Does the development and design of products/processes extend beyond a single function or a single firm to include suppliers, partners, or various other functional areas?[23] Is the design itself carried out in-house or through collaboration or separate research facilities?

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increased access are needed, and hence information systems play a central role; see also Shaft (1997).

[23] Coulter, Bras and Foley (1995) identified several different approaches (or philosophies) to address environmental impact: environmental engineering, pollution prevention, environmentally conscious design and manufacturing, design for the environment, life cycle design, green engineering, industrial ecology, and sustainable technology. Two basic factors were used to distinguish between them: *scope of environmental concern* and *scope of temporal concern*. The scope of environmental engineering and pollution prevention is narrow, dealing mainly with the manufacturing phase of the product life cycle. Life Cycle Design attempts to reduce risks and impact during production and use. Industrial ecology extends the scope to include several product life cycles over a larger time scale, to integrate the use of energy, materials and capital into a paradigm for the whole industrial *ecosystem*.

The next chapter describes two approaches to environmental production, which demonstrate a range from a somewhat limited perspective to a more inclusive or integrated one. The life-cycle approach addresses the processes in making, using and, in some cases, re-using and recycling products. The system for environmental management starts from a business management perspective instead of process and offers a way of including a range of concerns into a firm's operations. A wider scope of issues, a more extensive the stewardship of products, and distributed design all add to the complexity of environmental management and the need for effective knowledge management becomes greater.

Moving from a limited perspective to an integrated one means cutting across more knowledge boundaries, raising the challenges to knowledge sharing. Knowledge solutions and information technologies can be devised to overcome disconnects in a complex system, and to help retaining and creating more knowledge. A successful knowledge network can diffuse, through sharing and market mechanisms, better practices. It would help companies meet standards and expectations, and find possible win-win solutions, whereby the company increases competitiveness at the same time it reduces environmental impacts.

Chapter 4: Knowledge Networks for Sustainable Production

Environmental issues are fraught with spatial and temporal considerations. Pollution generated locally may aggregate to a global-level impact. Some emission is primarily global in character, such as greenhouse gases. Regulations vary from country to country, and in some places, firms have to start thinking about their responsibility from creation of a product to its disposal (extended product responsibility). There are also large-scale efforts to harmonize environmental regulation on a global basis. Furthermore, the issue of sustainable[24] use of resources raises the question of who will pay for the environmental problems generated now – future generations or current ones? In short, the corporation faces a myriad of issues, some of which it can no longer ignore or circumvent.

Firms generally see environmental regulation as a cost and have in the past not been particularly responsive to environmental issues (see Choucri, 1993). Environmental management emerged as a reaction to regulation, mainly to comply with end-of-pipe

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[24] Probably the best known definition of sustainability is "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs," (*World Commission on Environment and Development 1987*, p. 8). Choucri provides the following, and similar, definition: "We define sustainable development as the process of meeting the needs of current and future generations without undermining the resilience of the life-supporting properties or the integrity and cohesion of social systems." (http://gssd.mit.edu/). Other definitions are more based on business strategy. The International Institute for Sustainable Development and Deloitte&Touche propose this one: "For the business enterprise, sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining, and enhancing the human and natural resources that will be needed in the future," http://www.betterworld.com/BWZ/9610/explore.htm

effluence and emission standards. The implementation of technological solutions for environmental protection came across as direct cost to producers and they were inclined to resist regulation (Fischer and Schot, 1993). During the 1980s, consumer preferences and public opinion took on a growing role as drivers of environmental management. Firms had an incentive to work with regulation rather than resist it since environmental pressures were appearing on the demand side (Allenby, 1999; Fischer and Schot, 1993).

Nevertheless, environmental policies were still regarded as a cost on business and industry. Economic activity carries a social cost, which has to be assessed through valuation of nature and quality of life (such as health). The social benefits of regulation then have to be compared to the cost to the economy; environmental protection revolves around cost-benefit, or tradeoff, issues (Palmer et al, 1995). Even so, there is no strong evidence to support the notion that stringent regulation hurts industrial competitiveness (Choucri, 1995; Jaffe et al 1993).

More recently, some people have depicted innovation for environmental protection as a win-win situation for business as well as the public. According to this logic, environmental management forces firms to innovate, raise productivity, shift to service orientation, find niche markets, and anticipate (or shape) regulation (Allenby, 1999). Porter and Linde (1995) maintain that the debate over environmental goals and competitiveness has been incorrectly framed. The tradeoff analysis uses static methods, where the firm is assumed to have made all cost-minimizing choices. In such a static world, regulation necessarily raises costs. But in a dynamic world, competitiveness depends on innovation and productivity gains. Well-targeted regulation can trigger innovation and generate benefits that offset regulatory costs. This is possible because firms do not optimize all the time: technological opportunities change, information is incomplete, organizations are often inflexible and control difficult.

Innovation offsets affect both products and processes. Product offsets not only lessen pollution, they can also create higher quality products, safer products, reduce cost through material substitution, and so on. Process offsets might lead to better resource productivity, lower energy consumption, and reduced material storage and handling costs, to name some. In this sense, pollution is actually an indicator of inefficiency and incomplete capture of value (see Porter and Linde, 1995).

The proponents of the dynamic environmental competitiveness argument support it by several case studies[25]. Detractors (Palmer et al, 1995) point out that innovation offsets may indeed exist for some firms, but as a general rule it does not work. Cost-Benefit models as well as case study evidence show that for majority of firms, regulation is a real cost. But the dynamic view signals new thinking about corporate strategies that must take into account not only changing regulatory and consumer demand, but also environmental management as a positive influence on competitive advantage.

4.1 Life Cycle Analysis

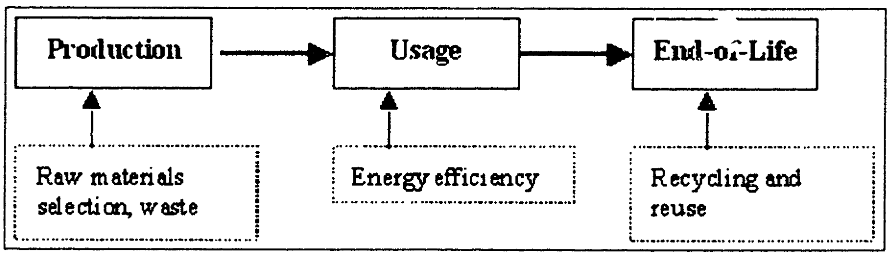
Theoretically, a life cycle approach seeks to minimize the overall environmental impact of a product or process. This approach factors in environmental concerns at each stage in the product life cycle, from material acquisition to disposal, or from 'cradle to

[25] For instance, in 1990 Raytheon set out to eliminate the use of ozone-depleting chlorofluorocarbons (CFCs) as a cleaning agent, in compliance with the Montreal Protocol and the U.S. Clean Air Act. Although at first complete elimination was considered impossible, Raytheon found a new cleaning agent which could be reused. The

grave', (Coulter et al, 1995). Broadly defined, life cycle analysis takes into account the safety, health and social factors across the life-span of a product, process, material, technology, or service. But in applied terms, it refers to methodologies and tools for quantitative analysis and assessment of material and energy inputs and environmental effects - i.e. Life Cycle Assessment or LCA. (Richards et al., 1994; Vezzoli, 1999).

For instance, pump-maker Flygt (part of ITT Industries group) considers three general phases: production, usage, and end-of-life, and measures the impact of each phase in Environmental Load Units, based on international guidelines.

Figure 10
Phases of The Life Cycle Approach



(Graph based on text in 1998 Environment, Safety and Health Report, ITT Industries).

The Europe-based project on Strategic Comprehensive Approach for Electronics Recycling and Re-use (1999) starts with the traditional product life chain, consisting of production, distribution and use. In a more detailed analysis, and as applied to the electronics industry, it has the following stages:

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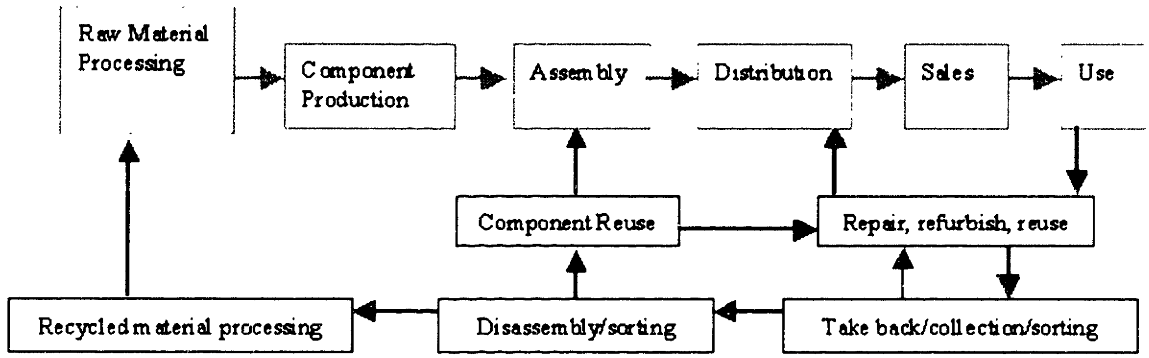
new method actually led to higher product quality and lower operating costs (see Porter and van der Linde, 1995).

Figure 11
Closing the Product Life Cycle



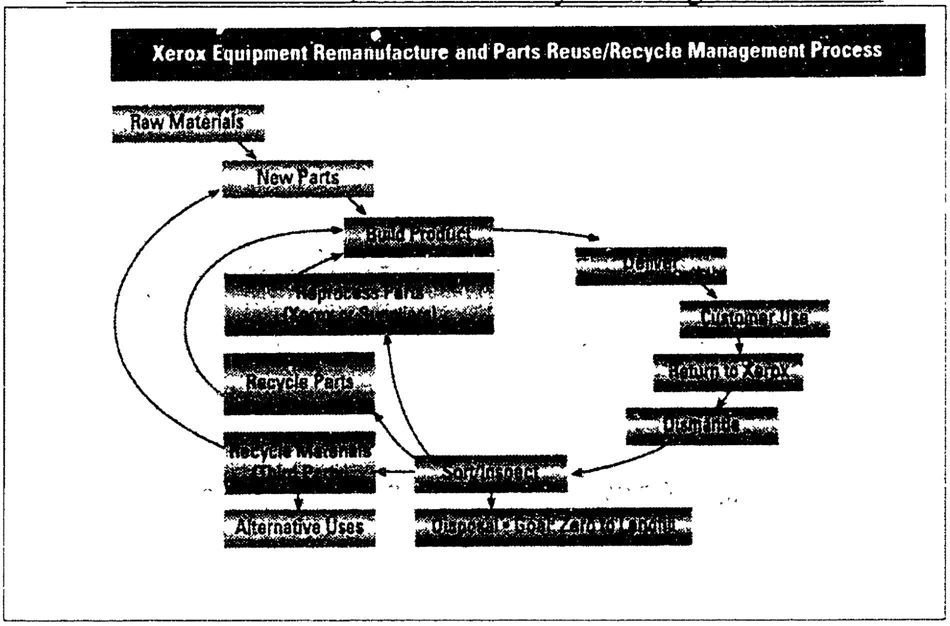
(Source: Adapted from SCARE, 1999.)

The object is then to reduce the consumption of materials and energy and control or eliminate use of hazardous materials, a goal referred to as 'thinning' the cycle.

What happens at the end of product life chain should influence decisions, design, and operations upstream. The concept of the product life cycle requires us to think about end-of-life management. The SCARE design explicitly closes the product life cycle by taking into account component design for reuse, materials for recycling, collection and sorting logistics, and so forth. It does not however treat the final stage, which is waste disposal, although it is implicit in environmental design for material control.

Xerox has developed a successful remanufacture and recycling process for its LAKES product line, sometimes referred to as 'zero-to-landfill', which aspires to complete elimination of waste. The project had to address materials use, assembly processes, component and modularity design, servicing and take-back logistics, and product ownership (customer leasing).

Figure 12
Xerox Remanufacture, Reuse and Recycle Management Process

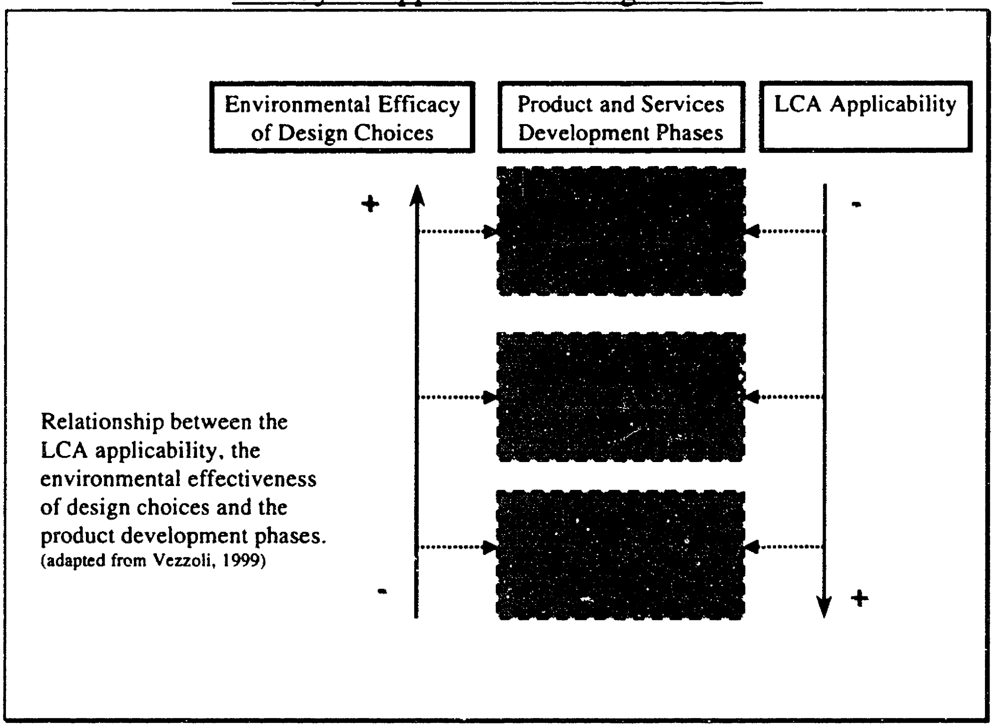


(Source: 1999 Environment, Health and Safety Progress Report Xerox)

Although an important improvement over pollution control, the LCA approach has been criticized for it's limited view of what is environmentally 'preferable'. According to critics (Richards et al., 1994; Vezzoli, 1999), LCA techniques do not give definitive answers to environmental effects because of assumptions about types and modes of pollution and energy. LCA models do not describe the whole range of environmental impacts. This has led Allenby (1999) to conclude that current Life Cycle Assessment methods are better suited to simple products, such as personal care products or plastic packaging.

Furthermore, LCA is mainly an analytic approach and does not directly address design issues. It's a methodology that requires data. As the product becomes more defined and specified LCA becomes more effective because more data is available. During the first phase, the strategic design of a product development, data is more scarce. But that is also the time when innovation for reducing environmental impact can be most effective as it is integrated into the whole design process (Vezzoli, 1999). In this sense, LCA can be thought of as an essential module in the overall environmental strategy and design - a piece of a company's environmental management system.

Figure 13
Life Cycle Approach and Design Choices



4.3 Environmental Management Systems

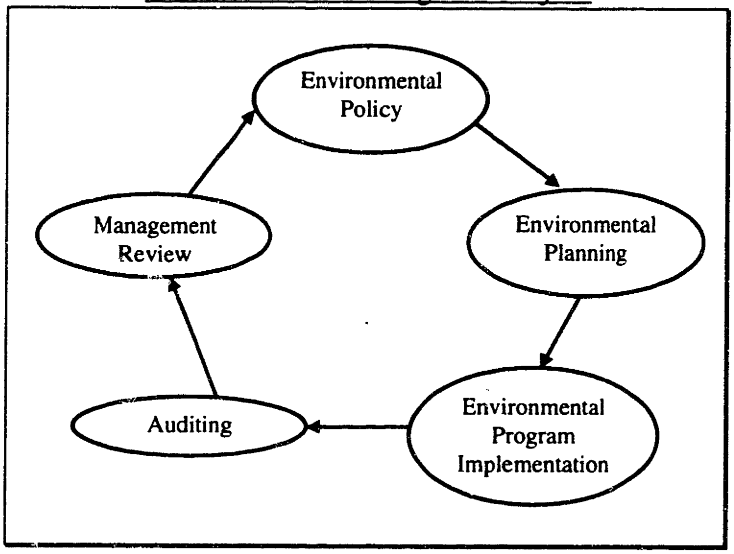
A subset of management systems in general, Environmental Management Systems are "formal structures of rules and resources that managers adopt in order to routinize behavior that helps satisfy corporate environmental goals," (Ehrenfeld and

Nash, 1999, p.1). Firms can develop their own EMS structures, follow trade association models and practices, or adopt standardized systems, such as ISO 14001.

In all instances, management must set goals, develop an implementation plan, gather information, track progress, institute training programs, and undertake corrective action when needed (Ehrenfeld and Nash, 1999). Environmental goals will vary depending on firms' industry, strategy, and culture, but in theory, properly executed EMSs can lead to improvements in environmental performance above basic compliance and policy requirements.

The ISO 14001 standard provides a common framework for a verifiable environmental management system. The framework does not prescribe detailed operating practices, but instead requires "organizations to establish a coherent, justifiable and consistently applied procedure for setting environmental policy goals, and to implement plans for achieving them,"(Nash et al, 1999, p.9). The ISO 14001 is based on a continues improvement model, or a "Plan-Do-Check-Act" cycle, with the following steps: environmental policy, environmental planning, environmental program implementation, auditing, and management review (ibid.)

Figure 14
Environmental Management Cycle



As in the case of any successful business strategy, environmental strategy requires effective management of technology, good understanding of markets, and awareness of the policy sphere. Good comprehension of the business environment, especially in global terms, requires knowledge, in terms of information flows, technological application, and for effective analysis. Competitive advantage belongs to those who acquire and direct intellectual assets (i.e., scientific knowledge, business information, and skilled workers), "which create knowledge into the future through their utilization," (Carayannis and Alexander, 1999, p. 327). The knowledge dimension may be particularly important in the case of environment-related operations because of new technological imperatives, changing consumer attitudes, and global reach of environmental issues.

Chapter 5: Knowledge and Sustainable Products and Processes

Knowledge and information technology requirements depend on operational scope. The following dimensions capture the main elements of sustainable products and processes for the purpose of mapping out the knowledge scope:[26]

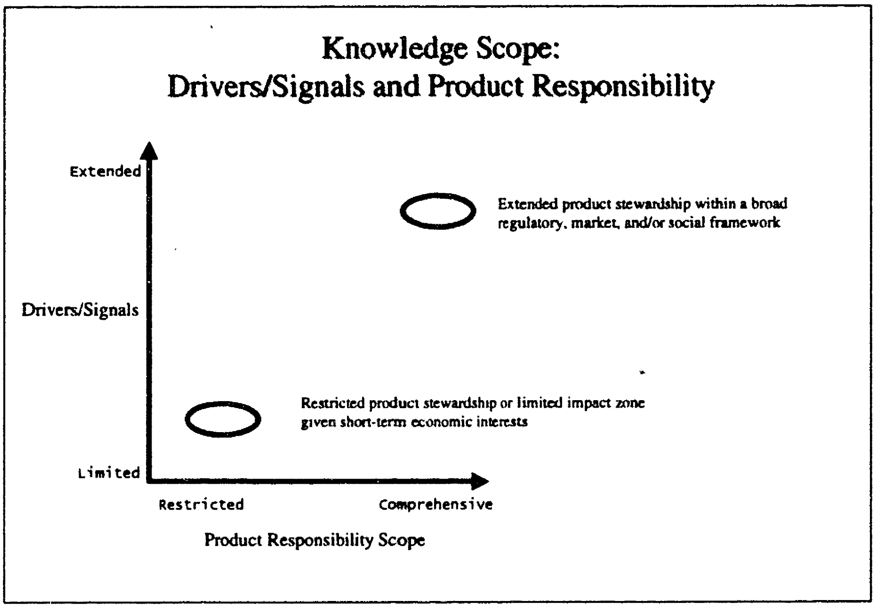
- *Scope of Drivers and Signals* (from short-term market to longer-term comprehensive)
- *Product Responsibility* (limited end-of-pipe to extended stewardship).
- *Locus of Design in Value Chain* (local in-house to distributed across functions and organizations)

Given the location of a firm or certain processes or products (a firm may have different standards or procedures for different product lines etc.) in relation to these dimensions, we can ask what scope and nature of knowledge is needed to operate at that level? A firm could be operating according to fairly simple 'end-of-pipe' effluence standards, mainly with local impact and short-term interests in mind, or it could taking into account extended standards for waste, energy efficiency, recycling, and re-use, as well as varying political and regulatory environment.

Figure places knowledge associated with sustainable products & processes on two axes: Drivers/Signals, ranging from limited scope to extended scope, and Product Responsibility, from restricted to comprehensive stewardship.

[26] Developed with Nazli Choucri, MIT, Department of Political Science, 1999.

Figure 15



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The Drivers/Signal dimension gauges the complexity and diversity of signals or drivers behind the development of sustainable or environmentally sensitive practices. Industry-society relationship has many facets (such as economic, political, technological, and ethical). At the lower end (limited scope) the firm reacts to short-term market signals. As firms move up the axis, the signals/drivers become more comprehensive and include political factors, technological developments, and regulatory structures. This is especially relevant in terms of globalization. Firms operating in the 'extended' environment take a 'longer-term' view and are generally pro-active or anticipatory. Representing Drivers and Signals in one axes, on one scale is a simplification. The knowledge space in the diagram could have several vectors, measuring different things, such as geographical boundaries (local, national, or international standards), issue areas, and technical aspects.

The Product Responsibility dimension refers to how far upstream and downstream a firm's stewardship extends. And it asks if the knowledge that goes into designing and making the product represents the whole life cycle, from material use to disposal? The Europe-based SCARE project (Strategic Comprehensive Approach for electronics Recycling and Re-use, 1999) seeks to reduce minimize, contain and control material and energy use in the electronics industry. Such a strategy requires consideration of the whole life cycle. And "in order to build this link between a more rational use of resources upstream and the product or its materials recovery downstream, a better knowledge of both product components and their impacts on environment is a necessary step," (p. 13). And it requires effective coordination between all actors in the value chain. The project outlines recognizes this and calls for the development of a shared information system to manage the program as well as provide essential data, information, tools and knowledge to participants at most levels.

Xerox's Lakes product line was guided by a 'zero to landfill' goal.[27] Everything had to be reused or recycled. The Document Centre 265 digital products were modular in design. Instead of performing major repairs on site, the service technicians would swap the problematic module, which would be shipped back for repair and used again in new products. This process requires effective coordination with the product line and suppliers. The Lakes products were also designed with minimal use of hazardous materials, low emission, and energy efficiency in mind. Hence, Xerox Lakes would rank high on the Product Responsibility Scope.

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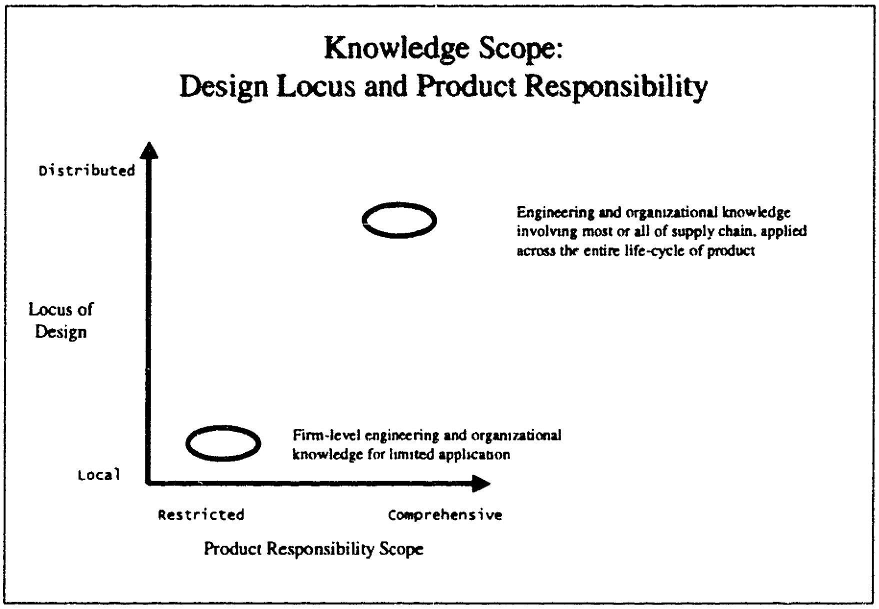
[27] Based on interviews with John Elter in 1999 (then Vice President, Strategic Programs, Xerox corporation) and Ott et al (1997).

Although primarily driven by the vision and, at the same time, functional goal of 100 percent take-back, Xerox had to consider environmental standards and regulation in major markets. As well as acquiring U.S. Energy Star designation, the Lakes products also complied with more stringent standards in Europe, such as the German Blue Angel, Nordic Swan, and the Swiss Energy 2000. So while the drivers or signals were mostly based on an environmental goal, they did extend beyond to incorporate a wider variety, moving the company up the Drivers/Signal dimension in Figure 12.

The next Figure introduces the Locus of Design in the value chain and maps it against Product Responsibility Scope. The Design dimension actually embodies two issues of distributed design. One is more geographically or physically based. In this case, the design for environment can be distributed, where suppliers are integrated into product design and process implementation, or a localized, which limits concerns to in-house operations. Separate design and production facilities might require a better information and knowledge flows. For example, the manufacturing process for 100 percent recyclable products, as in the case of Xerox Lakes, has to involve the whole supply chain. Suppliers have to manufacture to certain standards and designs and be able to re-use components. We could also ask whether suppliers can take an active role in innovation for the environment or if they will entirely follow requirements set by the core company.

The second issue is that of pulling together different communities of practice (specialist) into a single design process. In a more complex production, groups with different agendas and responsibilities need to be involved in the design process from the beginning (as in the case of product development) in order to increase efficiency and competitiveness. Similarly, environmental concerns may fall across several areas of product development (depending on goals and product responsibility), such as emission, material use, packaging, component reuse. These issues straddle knowledge boundaries of different practices and represent hurdles for overall design process and environmental goals.[28]

Figure 16



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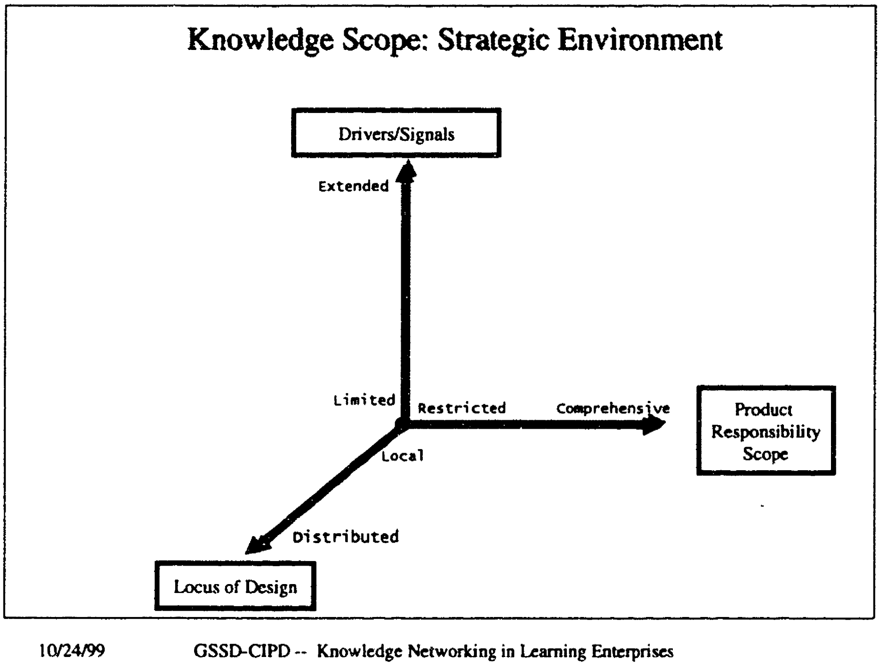
The last Figure combines the three dimensions we need to consider to map out the knowledge scope of sustainable products and processes. As firms move out on the axes

[28] Setting the environmental target higher can lead to better results by the way of forcing the company to deal with different knowledge boundaries. In 1987, Polaroid targeted a 10 percent yearly reduction in chemical use and waste for a five year period. The management instituted a complex accounting system, tracking 1400 materials, to measure progress. Although successful to begin with, the program slowed down in the fourth year. In light of declining profits, managers found it hard to maintain a tight belt on material use because of costs. The program was later replaced by more lax guidelines based on compliance. The Robbins company, a metal finisher and plater, set it's sights higher than Polaroid. Management decided to strive for zero discharge, or a closed-loop system. It took more effort, worker training and closer monitoring, but was deemed successful in reducing waste, higher product quality, and less costs (Nash and Ehrenfeld, 1999).

the complexity of their position increases and knowledge embodiment, acquisition and application grows.

Figure 17



Each of these dimensions anticipate organizational adjustments, knowledge management capacities, and advances in communication technologies. With few exceptions, if any, organizational complexity is increased, requiring added means of tracking and streamlining. The larger the size and extendedness of the enteprise, the more challenging are the organizational requisites (Choucri, 2000, p. 19).

By acknowledging and charting the complexity of sustainable production, the role of knowledge and communication technologies can be better appreciated and understood. Knowledge solutions and information technologies can be devised to overcome disconnects in a complex a system, and to aid with retention and creation of more knowledge. For instance, an electronic knowledge network would be useful to facilitate value chain communication and coordination for sustainable product processes and design. Collaborative tools can be applied within departments or functional areas in a firm as well as across supply chain. Knowledge networks can be thought of as infrastructure and connectivity that transfer knowledge for design with the whole product life cycle in mind.

Chapter 6: Conclusion

The thesis is motivated by two major trends: the rise of a global information and knowledge economy, and environmental degradation and the search for sustainable solutions. The increasing importance of knowledge has by some been equated with a new industrial revolution, one based on computer technology, digital infrastructure, and highly educated and technically skilled workers. In the information and knowledge economy, knowledge is an asset to be managed, nurtured and retained. In economic terms, knowledge has seized to be a residual of technology in the production function and can rightly be claimed as a factor of production.

But how do we assess the value of knowledge in this 'new' economy? The question over value is explored through the diffusion and localization of new knowledge via a knowledge network, based on information technology. The central argument is that in the knowledge economy, the value of knowledge lies in the ability to share it over a *knowledge network*, which allows for *diffusion* and *localization* of new knowledge.

This central thesis and the value the knowledge networks is further explored by looking at the case of environmentally friendly or sustainable production. Information and knowledge networking is increasingly being viewed as an essential module in the solution to environmental problems. The environmental dimension is an integral part to the operation of firms, given regulation, standards, organizations, consumer demands, and scientific discoveries, at both the local and global level. Effective knowledge management and networking form an essential part of the solution strategy for integrating environmental factors into corporate operations.

The first chapter compared the industrial revolution and the new knowledge economy, and explored whether the latter signals a fundamental shift in economic structures, from manufacturing to knowledge-based services and high technology sectors, where production of ideas, or knowledge, reigns. Although still in its early stages, the knowledge economy changes labor markets and business organization, as well as what constitutes value in the economy.

The following chapter discussed the value of knowledge. Knowledge can no longer be ignored as a residual in the production function. Rather, it has taken hold as a factor of production. This indicates that it might be treated as a commodity, shared and sold. The implications are that we have to think about knowledge value not just as an asset at the local level, but at a level which includes diffusion and localization of new knowledge. Central to such a process is a knowledge network, built on information technology. The transfer of knowledge over a network faces boundaries of varying complexity, depending on how embedded the knowledge is in local communities and how easily it can be represented by common language and categories.

Three boundary modes are used to analyze the ease or difficulty of transferring or sharing knowledge. The transfer, or syntactic, mode takes a syntactical view of knowledge and information. If entities share a syntax or categories and have adequate processing capacity, then knowledge can be transmitted. The translation, or semantic, mode recognizes that communication can be problematic because knowledge does not mean the same thing to all people and doesn't necessarily serve the same purpose. To overcome these boundaries, categories need to be translated for common interpretation. And finally, the transformation, or pragmatic, mode takes into account pragmatic boundaries between communities of practice. The locality shares understanding and categories and has invested the knowledge in certain purposes and ends. These pragmatic issues may be at odds with other groups and be dependent on each other. To share, communities have to devise a shared method, specify their differences and dependencies, and then alter boundaries through transformation of knowledge.

As boundaries are overcome, more and more knowledge is then brought to the arena where it can be of value to others and help generate more knowledge. In this sense, the growing connectivity and the creation of new tools and contents have the potential to increase the value of knowledge. The situation can also be viewed from the angle of value-added of knowledge. The increased recognition of the value of knowledge drives the level of knowledge intensity and changes in knowledge boundaries. There is more demand and need for solutions.

The next two chapters turned to the concepts of knowledge networks in terms of environmentally sustainable production. The first discussed some environmental imperatives for firms and introduced two solution strategies, life cycle and environmental management systems, to demonstrate the rising complexities and knowledge needs. The final chapter charted the knowledge scope for environmental solutions, with the objective to develop common categories for knowledge analysis, and to understand better the increasing complexities and information/knowledge needs as enterprises engage in sustainable production. Through this we can identify critical areas or processes for enterprises that seek to learn from each other through sharing of some sort in the domain of sustainable production. From there we can begin to clarify the types of connectivity, the ways of providing content and the characteristics of the tools that can benefit creating sustainable products.

In discussing the knowledge economy and knowledge networks, the thesis has focused mostly on the business enterprise. But the development of the knowledge age has much larger implications, such as 'knowledge for whom?' and 'value for whom?'. The information technologies and networks offer new ways for people and groups to interact and influence social issues and can enable the diffusion of wide variety of views and perspectives. They have the potential to reduce barriers to access and equalize participation in the political, social, and economy spheres (Choucri, 1999). The knowledge boundaries then become tightly integrated with social boundaries, with the question over power, social policies, public and private benefits, and even economic development. Increased and more open diffusion of technological knowledge may allow less developed economies to leapfrog past established technologies and find competitiveness in new industries (Choucri, 1999; World Bank, 1999).

Thinking about the information and knowledge age in the larger economic and social context requires us to consider who builds, controls, influences and benefits from the technology and its use. Before we can reasonably approach this analysis, a basic conceptual framework or understanding of knowledge sharing, knowledge networks, and value of knowledge is called for. This thesis is a building block for such a framework, a contribution to future research into the economic and social implications of the knowledge economy.

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