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Knowledge and its Economic Characteristics – A Conceptual Clarification

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Knowledge and its Economic Characteristics – A Conceptual Clarification

March 2007

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Abstract

This paper discusses several features of knowledge that are often considered crucial for characterizing the economic significance of knowledge: whether it is overtly accessible or tacit, whether it can be or is encoded or not, and whether it has public or private good character. It is argued that all these features depend similarly on the state of the knowledge technology, i.e. on how knowledge can be acquired, stored, used, and communicated. The different characteristics and the relationships between them are shown to correspond to different specifications of the technology, specifications that are not always made explicit in the literature.

JEL-classification: D83, O31, O34

Keywords: knowledge, knowledge technology, tacitness, overtness, public goods, intellectual property rights

I. Introduction

It is broadly acknowledged now that knowledge plays a crucial role for understanding technological change and its impact on economic activities (cf., e.g., Feldman 1994; Nonaka, Toyama and Nagata 2000; Antonelli 2001; Mokyr 2002; Murmann 2003). With a growing body of research in economics focusing on the role of knowledge, a growing number of concepts and classifications of knowledge have been developed since the first elaborate attempt in that direction by Machlup (1980). One distinction that, among others, will serve as a reference here goes back to Polanyi (1958). It is the widely used distinction between tacit and overt, or implicit and explicit, knowledge (see Cowan and Foray 1997; Cowan, David and Foray 2000 and the literature cited there). While knowledge is considered overt when it is openly accessible to everybody and understandable, for tacit knowledge this is considered not to be the case (Cowan and Foray 1997; Zack, 1999; Cowan, David and Foray 2000; Lissoni 2001).

A distinction like this is made with the intention to bring out characteristics of knowledge that are regarded as significant. Yet, what the significant characteristics are depends on the context. Distinguishing tacit from overt knowledge does not seem of much help, for instance, in deciding whether or not knowledge has a public good character – a question that figures prominently in the economic literature (e.g. in welfare theory, see Arrow 1962 or new growth theory see Langlois 2001). Some authors claim that, once knowledge exists, it has properties of a public good (Nelson 1959; Arrow 1962; Foray 2004; Brusoni, Marsili and Salter 2005) or at least of a local public good. Others consider knowledge a private good (e.g., Callon and Bowker 1994). It seems worthwhile, therefore, to clarify how different characteristics of knowledge relate to each other and which ones matter when.

This chapter is devoted to exploring this question. We will argue that the different characteristics of knowledge – its overtness or tacitness and its public or private good property – depend equally on the state of the knowledge technology, i.e. on how knowledge can be acquired, stored, used, and communicated (cf. Nelson and Nelson 2002). Different specifications of the characteristics therefore correspond to different assumptions about the knowledge technology, assumptions that are not always made explicit. To make our point, we will start with a brief outline of the technological underpinnings of knowledge storage, expression, and transfer in Section II. The insights gained at that level suggest modifications regarding the distinction between overt and tacit knowledge on the one hand and encoded and non-encoded knowledge on the other that are discussed in Section III. Section IV then turns to the public vs. private good characteristics of knowledge and derives the implications of our interpretation. Section V presents the conclusions.

II. Knowledge Storage, Expression, and Transfer

Knowledge is accumulated over time at the level of each human being, at the level of groups of individuals like in a firm organization, and even at the level of the entire economy. The accumulated body of knowledge can be stored in a variety of ways, from the individuals' memory to diverse technical media, and it can be embodied in artifacts. As long as in human

history there was no possibility to encode knowledge, knowledge could only be stored internally, i.e. in the individuals' memory. This kind of storage 'technology' humans are naturally endowed with has a limited capacity, accessibility, and reliability, and suffers, moreover, from the constrained life time of the individual agents. Once ways had been found to encode knowledge on suitable artificial media this meant that an external storage technology had become available that was not subject to the same constraints as human memory. On the other hand, with the physical separation of the storage of knowledge in artificial media and its use, that still requires the involvement of individual human minds, it becomes evident that stored knowledge as such does not produce any effect.

Knowledge becomes effective – and economically relevant – only when it is accessed and processed by a human mind and eventually 'expressed' by some action. The processing involves more or less idiosyncratic, subjective interpretations. For this reason, knowledge, even when stored as a given body on artificial media, can find expression in different thoughts and actions by different agents. To enable the agents to activate knowledge stored in codified form external to the individual brain and express it by their actions, two preconditions must be given. The agents need to have access to the stored knowledge, and they must have a cognitive "absorptive capacity"¹ that allows them to understand the code and interpret context and meaning of what is stored. (Note that the encoding and storage of knowledge or its embodiment in artefacts is also a form of expressing knowledge.)

Access to externally stored knowledge is already an aspect of knowledge communication in which there are transmitters and recipients. It is useful to distinguish here between direct and indirect communication and between whether knowledge is intentionally or non-intentionally communicated. Knowledge is communicated *directly* only in oral or visual transmissions requiring face-to-face contact between transmitter and recipient – the communication technology that humans are naturally endowed with. It determined the constraints on knowledge transfer for the part of human history in which the encoding of knowledge was unknown. An *indirect* communication of knowledge is mediated by encoding the knowledge and transmitting it via, or storing it on, an artificial medium that can (later) be accessed by the recipient(s).² Indirect knowledge transmission relies on optical, acoustic, or electronic signals. Examples of

¹ Cohen and Levinthal (1989). Unlike in the present individualistic interpretation, they do not consider storage, access, and communication of knowledge in detail, but define conditions under which (firm) organizations are capable of absorbing new scientific developments into their R&D activities.

² Something similar holds for user knowledge inherently embodied in artefacts, e.g. tools like a knife, a bow, or an ax. If such an artefact is unknown to an agent she may be unable to produce or even design it by herself. When finding such an artefact, however, it may be possible for the agent to infer its purpose (what it is good for) from the features of the artefact – in which case the knowledge of its producer is indirectly conveyed. The argumentation relating to artificial media in this paper may therefore be extended *mutatis mutandis* to artefacts embodying knowledge.

communication by means of intermediate knowledge storage are written documents and visual and acoustic displays. Indirect communication thus presupposes codification of knowledge and an external storage technology. Knowledge is *intentionally* communicated when a sender deliberately transmits knowledge to some recipient(s), be it directly or indirectly. Knowledge is communicated *unintentionally* in two forms:

- in direct communication when it is implicitly expressed by the action of an agent that, if observed, allows the observer to make an inference from the action to the underlying knowledge;
- in indirect communication when agents gain access to knowledge encoded on, and/or transmitted by, an artificial medium whose access has not been intended by the transmitter and/or the legal owner of the storage medium. Unintentional knowledge transmission is often involved when action or artefacts are imitated.

Indirect communication making use of technical media enables a more powerful knowledge transfer than direct communication. The reason is that several individuals can have a multiple, often even parallel, access to the storage medium. Moreover, the way in which knowledge can be communicated becomes independent of the physical presence of particular agents who hold that knowledge in their memory. Furthermore, in a technical storage medium, knowledge can be structured and retrieved in a much more systematic way and by the effort of several people.³ However, since indirect communication hinges on knowledge codification, its power is constrained by the state of, and the historical progress in, the encoding technology. For this reason, accelerations in the rate of knowledge communication and accumulation are correlated with major technical breakthroughs in codification – from the invention of writing to that of the printing press to the development of electronic encoding and automatized processing of the code (Dudley 1999). However, independent of the great leaps forward in the encoding technology and the enormous growth of the body of encoded knowledge, in order for knowledge to become effective and economically relevant it still needs to be expressed by individual minds. This means that, because of their limited life time, each human generation has to acquire the growing knowledge anew in an incessant inter-generational knowledge transfer.

III. Three Types of Knowledge

There seems to be a consensus that overtness of knowledge means that knowledge is, in principle, freely accessible by everyone and – if encoded – has a commonly understood code. (Actual accessibility depends, of course, on what proprietary regime can be enforced, see the next section.) In an interpretation in which overt and tacit knowledge are polar cases, the degree of overtness and, conversely, of tacitness can vary between the extremes (cf., e.g. Saviotti 1998). As Nelson and Winter (1982, p. 78) note, “tacitness ... is a matter of degree (and) ... the same knowledge, apparently, is more tacit for some people than for others”. However, in contrast to the notion of overt knowledge for which the characteristics of accessibility and intelligibility are decisive it is not clear whether tacitness of knowledge means just the opposite with respect to

³ Cf. Foray (2004, Chap. 4) who considers this the most important advantage of encoded knowledge.

these two characteristics or whether it refers to some other characteristic(s). Indeed, it seems rather controversial what precisely tacitness of knowledge means.⁴

In the original statement in Polanyi (1958), tacitness refers to knowledge that is ill-defined, cannot be articulated, and may not even be fully recognized. A frequently given example of tacit knowledge is the knowing how to keep balance in riding a bicycle. As everyone who has tried to teach someone else riding a bicycle is aware of, this know how cannot be verbally described. It has to be acquired through trial-and-error learning by each individual anew. (Some hints that may ease the learning process may, of course, be helpful in the learning process as may be the observation of how others bike.) As Polanyi, (1966, p. 4) put it, “we know more than we can tell”. This means that even though tacit knowledge can be expressed by an action (biking), it defies a verbal articulation (cf. Winter 1987). As a consequence, it cannot be encoded, i.e. given a (complete) description of how to do it. Hence, it is not in the first place a matter of accessibility and intelligibility that makes tacit knowledge differ from overt knowledge. Rather it is the fact that tacit knowledge does not lend itself to encoding and, for that reason, is not (easily) accessible and intelligible. Thus, in our understanding of tacit knowledge, what is causal for the difficulties in accessibility and intelligibility that impede the transfer of tacit knowledge are a lacking encoding which, in turn, follows from a lacking articulability.

With a somewhat different emphasis, Brusoni, Marsili and Salter (2005) suggest an interpretation of tacit knowledge as “the inarticulable contextual framework(s) that provides individuals’ cognitive processes with the background within which to focus and to attribute meaning to contingent statements”. Encaoua, Hall and Laisney (2000, p. 193) argue that tacit knowledge is characterized by “a higher degree of uncertainty and the precise meaning is more interpretative and is not easily conveyed in a standardized medium.” Obviously, some additional characteristics are introduced in these interpretations while the precise relationship between tacitness and the encoding problem remains unclear. The characteristics Encaoua, Hall and Laisney (2000) attribute to tacit knowledge can also be satisfied by knowledge that is for some reason or other not (yet) encoded. However, knowledge that is not encoded does not necessarily have to be tacit. There is a difference between non-codified knowledge that can, in principle, be encoded and knowledge that cannot (Cowan, David and Foray 2000; Balconi 2002). Knowledge that cannot verbally be articulated surely is “uncodifiable knowledge” (Grimaldi and Torrisi 2001). People may not even be aware of it (Nelson 1982). This indeed comes close to Polanyi’s original notion of tacit knowledge as “distinct from, but complementary to, the knowledge explicit in conscious cognitive processes” (Cowan, David and Foray 2000).

Thus, while tacitness of knowledge implies that this knowledge is not encoded, the converse is not true. Knowledge that, at some point in time, for some reason is not codified, can be codified at a later point in time unless it is inherently non-codifiable. Only in the latter case it is tacit knowledge. As mentioned, the reason for the non-codifiability of tacit knowledge is that

⁴ Cowan, David and Foray (2000) express concerns that the variety goes so far that the very notion of tacitness becomes blurred.

it is not articulable. However, even this characteristic may in some cases disappear over time. As a result of discoveries and systematic scientific research previously tacit knowledge may become articulable as Lazaric, Mangolte and Massué (2003) have found in their case study of the French steel industry. Moreover, progress in production organization and increasing automatization often makes tacit knowledge obsolete (Balconi 2002). However, this is not to claim that tacit knowledge is generally of declining importance. There are many cases where tacit knowledge can be expected to become neither articulable nor obsolete – particularly where sensory capacities and intuition matter (like in many cognitive tasks) or where subconscious control of motor skills is an important part of tacit knowledge (like in biking and many other cases of learning-by-doing).

Hence, we arrive at three distinct types of knowledge. The first is codified knowledge. The second is non-codified but, in principle, codifiable knowledge. The third is knowledge that is inherently non-codifiable (at least at the given time) and therefore tacit. In practice, the three types of knowledge may be activated simultaneously or sequentially. Imagine, for example, an agent who needs to work with a new laboratory equipment. A large part of knowledge on how to use the equipment can be obtained from the manual (the codified knowledge part). Additional non-codified knowledge can be obtained by asking experts who have already collected experiences with the same equipment. The user knowledge they communicate can be more specific than the manual. (This additional user knowledge could, in principle, be encoded, if there were incentives to do so.) Finally, by working with the equipment on the job, the agents may acquire an own user know how, e.g., with respect to handling the equipment. It allows the agent to run down a learning curve in operating the equipment. The latter kind of know how may in part be unconscious. Like in the balance-on-the-bicycle example, such know how or parts of it cannot be articulated at all. It is the tacit, non-codifiable part of the agent's knowledge.

The differences in articulation and codification determine the specific storage and transfer conditions of the three types of knowledge. Concerning the storage aspect, unlike in the case of codified knowledge, all non-codified knowledge, tacit or not, can only be stored in human memory. When it is sometimes argued that non-codified knowledge is stored in organizations and institutions (Cowan and Foray 1997) or in organizational routines (Nelson and Winter 1982, Winter 1987), this is therefore only a short-hand way of saying that people involved in organizational routines and interactions within an organization like a firm hold in their individual memory a shared knowledge of how to interact. Concerning the knowledge transfer aspect, unlike in the case of codified knowledge, all non-codified knowledge, except tacit knowledge, can only be transmitted directly in a face-to-face interaction. Tacit knowledge cannot be inter-personally transmitted, not even through observational learning. To see someone expressing her knowledge of how to keep balance while riding a bicycle is not sufficient to acquire that know how. This has to be done through own trial-and-error learning.

IV. When Is Knowledge Indeed a Public Good?

A question economists have been concerned with since long is whether knowledge is a public or a private good. As is well known, a pure public good is characterized by two criteria. There is no rivalry in its use – the fact that the good is used by some agent does not affect the utility of other agents who also use the good – and there is no possibility to exclude anyone who wishes to use the good (no private appropriability). For a purely private good the opposite is true. The two criteria are independent of each other, and there are many goods which have only one of the two properties: non-rivalry in use *or* no exclusion of potential users (so-called impure public goods, cf. Sandler 1975).

It is often argued that knowledge has the properties of a public good (Nelson 1959; Arrow 1962; Teece, 1986; Callon and Bowker 1994; Beise and Stahl 1999; Roberts 2001, Foray 2004, Chap. 6). It is not the place here to appraise all facets of that debate. The aim rather is to reappraise the role of the technical terms by which knowledge can be stored, accessed, and transferred for assessing the public-vs-private-good nature of the different types of knowledge. The role seems quite obvious as far as the rivalry-in-use criterion is concerned. A significant feature of knowledge encoded on an artificial medium is that it can be re-used many times and by all agents with the corresponding absorptive capacity without being instantaneously erased or degraded (Langlois 2001). The more often the technical features of a storage medium allow the stored knowledge to be re-read, the less physical rivalry in use, i.e. in getting hold of stored knowledge, is to be expected. Take, for example, the knowledge encoded in a book or on an electronic device like a hard disc. As the knowledge stored does not disappear by being read, re-reading of the content of such storage media is possible many times. Their re-use may be subject to some tear and wear so that their physical life time is limited. On the other hand, the same content can usually be copied onto an arbitrary number of additional carriers (books, CDs) at minor costs.⁵

However, the absence of physical rivalry in accessing an encoded knowledge is not sufficient to satisfy the public good property. As mentioned, it is not the stored knowledge as such that is economically relevant, but the expression of that knowledge in individual thought and action. The utility or the economic value derived from ideas and/or actions thus generated may, of course, decline the more frequently they are expressed. Imagine, for instance, that the knowledge about how to produce a certain chemical is described (encoded) in a scientific book. After reading the book the know how can be expressed by, and may become commercially valuable to, every agent who has the suitable absorptive capacity and who engages in a production effort. The more agents indeed start producing the chemical, and the more intense competition therefore becomes, the less commercially valuable the know how encoded in the scientific book of course becomes. The profitable business opportunity it initially offered can be competed away.

⁵ For expository convenience we do not account here for bottlenecks in accessing a particular storage medium like a book or a hard disc which may, of course, ration their use and, thus, the knowledge expression at any point in time.

In cases in which the value of knowledge declines with its repeated expression, knowledge obviously fails to satisfy the non-rivalry-in-use criterion. (Note, however, that the value of knowledge does not generally vary inversely with the number of knowledge users. There are significant cases in which the value of a piece of knowledge even increases with the number of agents applying it, as is known from the literature on increasing returns to the adoption of network goods, see Arthur 1994). For this reason alone, knowledge cannot generally be considered a pure public good. Technical media on which knowledge is encoded can usually be accessed with low or no physical rivalry. Yet precisely because of this fact, wherever the value of a specific piece of knowledge declines with its diffusion, the technically feasible, frequently repeated expression of the stored knowledge induces rivalry in (the value of its) use. In so far, knowledge assumes the characteristics of a private good.

A similarly mixed result obtains with respect to the exclusion criterion. Again it is useful to first have a look at the technical terms on which some particular piece of knowledge can be accessed. Agents can always express the knowledge they hold in their *own* memory. They can also express knowledge stored extra-personally, provided they get access to it and can absorb it. One case in point is indirect communication in which, as discussed above, agents access knowledge encoded on an artificial medium (which, for the present context, implies that the agent is not excluded by another party from accessing the medium.) Another case is that of direct communication – be it intentional or unintentional. An agent then gains access to knowledge either by deliberate communication, e.g. by other agents giving her or him instructions. Or knowledge is conveyed unintentionally when the agent observes its expression in the actions of others.

Unlike in the case of deliberate communication where exclusion is not intended, unintentionally communicated knowledge is often the result of failure in excluding others. Indeed, the extent to which exclusion can be practiced in direct or indirect communication depends on several factors. Actions can have inherent features that make it more or less difficult to infer the knowledge implicitly expressed by them from observing the action. Or there may be technical devices and/or legal regulations factually preventing the observation of actions. Finally, the absorptive capacity and the memory capacity of observers matters. In any case, access by others to knowledge implicitly conveyed by actions – and thus the imitation of the knowledge expression – can only safely be prevented through secrecy, i.e. through keeping observers out. Precisely this is, of course, often incompatible with the way in which knowledge can be commercially exploited.

The access conditions (conditions under which exclusion cannot be practiced, as required for a purely public good) depend on the type of knowledge discussed in Section III. By its very nature, tacit knowledge does not satisfy the conditions for a purely public good. The reason simply is that tacit knowledge needs to be produced by each agent by her or his own trial-and-error learning – a natural barrier to a costless access. This restriction does not exclude, of course, that other agents, who observe someone exercising her or his tacit knowledge, are induced to start an own trial-and-error process which would neither have been induced nor perhaps have a chance to be successful without such an observation. Observing the actions by which other agents express their tacit knowledge does not suffice, however, to convey that tacit knowledge.

Such actions rather convey related, not (yet) codified knowledge which could, however, be verbally described and, hence, be codified.

With respect to non-codified, but codifiable knowledge the question of whether and how exclusion is possible requires a different answer. As long as it is not (yet) codified, this kind of knowledge is stored in the memory of some agent(s). It can be accessed by other agents only if it is revealed in direct communication either intentionally or unintentionally. Since by intentional communication access is deliberately granted, the crucial case is that of unintentional communication. As discussed before, the degree of exclusion here depends either on how far other agents can be prevented from observing the action potentially conveying the non-codified knowledge – the case of secrecy. Or it depends on the extent to which observers are unable to infer the knowledge underlying an action, e.g. because they command an insufficient absorptive capacity.

Similar conditions hold for codified knowledge when potential user can physically be excluded from the artificial medium on which it is stored, but not from observing the expression of the knowledge in corresponding actions. If the knowledge is conveyed by the observation this amounts to the case of unintentional direct communication. An example may help to illustrate the point. Imagine a public music performance in which an artist plays a newly composed piece of music on her instrument. (The very art of playing the instrument to perform the music is based on tacit knowledge that, for the reasons explained, is no pure public good.) Assume that the piece is played from a sheets of music (codified knowledge) inaccessible to the audience or that it is played by the artist by heart (non-codified, but codifiable knowledge). In both cases no transfer of knowledge (of the piece of music) by indirect communication can occur. However, by the very nature of the public music performance as an act of direct communication, the audience can gain access to the knowledge by listening to the piece. The condition again is that the audience has a sufficient absorptive capacity – in this case sufficient to recollect the music from hearing the performance. The example and the conditions that need to be met can be generalized for knowledge, whether codified or not, to become something of a “local public good” (cf. Cornes and Sandler 1991), i.e. a good freely accessible and reproducible by all agents involved in direct communication in a given location, a sufficient absorptive capacity presumed.

Concerning codified knowledge, physical exclusion is possible whenever physical access to the medium can be prevented *and* unintentional direct communication via the observation of the knowledge expression does not occur or can also be prevented. Where these conditions are met, encoded knowledge is not a purely public good even if there is no rivalry in use. (Where these conditions are not met, encoded knowledge can factually retain its character as a private good, if those who can gain access lack the necessary absorptive capacity to grasp the knowledge.) In the literature, the encoding of knowledge is sometimes held responsible for a metamorphosis of knowledge from a private to a public good. For example, Saviotti (1998) writes: “it seems intuitively clear that when a piece of knowledge is completely codified, and when all agents know the code, then every agent in the population is capable of rapidly retrieving and using such a piece of knowledge”. Yet, in the light of our discussion this is true only, if the codified knowledge is freely accessible. This condition is met in the case of published scientific knowledge, a case that writers like Saviotti perhaps presuppose. But the

condition is certainly far from being generally valid. Codification is but the prerequisite for storing knowledge outside human memory. How that external storage is made use of, and by whom, does not hinge on codification, but on the technical features and costs of controlling access to the storage.

A degradation of the private good character of knowledge, codified or not, can however occur through an uncontrollable diffusion. Indeed, this seems to be the most important, though of course not generally valid, argument in favor of assigning knowledge the character of a public good. If the only way of commercially exploiting a piece of knowledge is to express it in the presence of a paying audience or to sell it in a form encoded, e.g. on print media or electronic media, a further diffusion of that piece of knowledge beyond the original transaction partners may be difficult to keep under the control of the original proprietor. It is particularly difficult, if the piece of knowledge can not only be re-accessed over and over again via the same technical storage medium, but also be easily copied onto additional media. Nonetheless, lack of control over the further diffusion of a piece of knowledge, that can gradually turn it into a public good, does not hinge on whether knowledge is codified or non-codified. It is a problem of unintended communication and the technical means to prevent it.⁶

V. Conclusion

This chapter started with a brief outline of the technological underpinnings of knowledge storage, access, and transfer. The discussion suggested to reconsider the frequently used distinctions of overt vs. tacit knowledge and encoded vs. non-encoded knowledge and the relationships between them. As a result we found it necessary to distinguish at least three types of knowledge. The first type is encoded knowledge that can be considered overt knowledge, if and only if the medium on which the knowledge is encoded is freely accessible and the code is commonly known. The second type is non-encoded knowledge that can, however, be articulated and, hence, be encoded in principle. As long as it is not yet encoded, this type of knowledge can be considered overt only if two conditions are satisfied: when somebody who holds that knowledge expresses it through an action (e.g. articulating it) this must be observable, and it must be possible to infer the knowledge from the observed action. The first condition presupposes an opportunity to participate in what we called direct, face-to-face based communication that must, moreover, be non-discriminatory. The second condition is in the literature implicitly assumed to be satisfied precisely because the knowledge is articulable. It is the latter condition that makes the difference for the third type of knowledge that we distinguish. This is (at least at the given point in time) non-articulable and therefore inherently non-codifiable or, in short, tacit knowledge. This kind of knowledge cannot be inferred from

⁶ The value of knowledge stored on a movie DVD is, for example, almost non-appropriable these days, because it can be reproduced at almost no costs. But when a certain encryption is used, reproduction costs rise significantly and so do the costs of accessing the DVD content – without the original information (knowledge) being changed at all. The encryption code is a feature of the communication process, not of the knowledge itself.

observing someone expressing it as is epitomized by the example of keeping balance in riding a bike.

It has furthermore been shown in the paper that the technical terms of storing, accessing, and transferring knowledge also affect the key characteristics of knowledge regarding its public good character. Concerning the characteristics of rivalry in, and exclusion from, the use of knowledge, both have been argued to depend on the locus and technology of storing and communicating knowledge. Where and how knowledge is stored and can be accessed decides how and by whom it can be “expressed” (used). For this reason, the three different types of knowledge that have been distinguished have to be assessed differently with respect to their public-vs-private-good character. As long as knowledge is exclusively stored in the memory of one individual, it is a purely private good in a trivial sense. Once it is released this can, but does not have to be, different. People may still be excluded from the communication in which an agent expresses the knowledge she or he holds. Similarly, when knowledge is stored outside the individual’s memory – which presupposes its encoding – storage technology may still allow to control the access by others. Furthermore, only if people have an absorptive capacity that allows them to acquire communicated or accessed knowledge and to exploit it without destroying it (no rivalry in use), that knowledge may indeed take on the characteristics of a public good.

References

- Antonelli, C. (2001). *The Microeconomics of Technological Systems*, Oxford: Oxford University Press.
- Arrow, K.J. (1962). Economic Welfare and the Allocation of Resources for Invention. In: Nelson, R.R. (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton University Press.
- Arthur, B. (1994), *Increasing Returns and Path Dependence in the Economy*, Ann Arbor: University of Michigan Press.
- Balconi, M. (2002). Tacitness, codification of technological knowledge and the organization of industry. *Research Policy*, Vol. 31, No. 3, pages 357–379.
- Beise, M. and Stahl, H. (1999). Public research and industrial innovations in Germany. *Research Policy*, Vol. 28, No. 4, pages 397–422.
- Boschma, R. A. (2005). Proximity and innovation: a critical assessment. *Regional Studies*, Vol. 39, No. 1, pages 61–74.
- Brusoni, S., Marsili, O., and Salter, A. (2005). The role of codified sources of knowledge in innovation: Empirical evidence from Dutch manufacturing. *Journal of Evolutionary Economics*, Vol. 15, No. 2, pages 211–231.
- Callon, M. and Bowker, G. (1994). Is Science a Public Good? Fifth Mullins Lecture, Virginia Polytechnic Institute. *Science, Technology, & Human Values*, Vol. 19, No. 4.
- Cohen, W. and Levinthal, D. (1989). Innovation and Learning: The two Faces of R&D. *Economic Journal*, Vol. 99, pages 569–596.
- Cornes, R. and Sandler, T. (1991). *The Theory of Externalities, Public Goods, and Club Goods*. Cambridge Univ. Press, Cambridge.

- Cowan, R., David, P. A., and Foray, D. (2000). The explicit economics of knowledge codification and tacitness. *Industrial and Corporate Change*, Vol. 9, 211–253.
- Cowan, R. and Foray, D. (1997). The economics of codification and the diffusion of knowledge. *Industrial and Corporate Change*, Vol. 6, 595–622.
- Dudley, L. (1999), *Communications and Economic Growth*, *European Economic Review*, Vol. 43(3), 595-619.
- Encaoua, D., Hall, B., and Laisney, F. (2000). *The Economics and Econometrics of Innovation*. Kluwer Academic Publishers, Boston.
- Feldman, M. (1994). *The Geography of Innovation*. *Economics of Science, Technology and Innovation*, Vol. 2, Kluwer Academic Publishers, Dordrecht.
- Foray, D. (2004), *Economics of Knowledge*, Cambridge, Mass.: MIT Press.
- Grimaldi, R. and Torrisci, S. (2001). Codified-tacit and general-specific knowledge in the division of labour among firms -A study of the software industry. *Research Policy*, Vol. 30, No. 9, pages 1425–1442.
- Langlois, R.N. (2001)
“Knowledge, Consumption and Endogenous Growth”, *Journal of Evolutionary Economics*, Vol. 11, 77-93.
- Lazaric, N., Mangolte P.-A., and Massué, M.-L. (2003). Articulation and Codification of Collective Know-how in the Steel Industry: Evidence from Blast Furnace Control in France. *Research Policy*, Vol. 32, 1829-1847.
- Lissoni, F. (2001). Knowledge codification and the geography of innovation: the case of Brescia mechanical cluster. *Research Policy*, Vol. 30, No. 9, pages 1479–1500.
- Machlup, F. (1980)
Knowledge and Knowledge Production, Princeton: Princeton University Press.
- Mokyr, J. (2002), *The Gifts of Athena – Historical Origins of the Knowledge Economy*, Princeton: Princeton University Press.
- Murmann, J.P. (2003), *Knowledge and Competitive Advantage*, Cambridge: Cambridge University Press.
- Nelson, R. R. (1959). The Simple Economics of Basic Scientific Research. *The Journal of Political Economy*, Vol. 67, No. 5, pages 297–306.
- Nelson, R. R. (1982). The Role of Knowledge in R&D Efficiency. *The Quarterly Journal of Economics*, Vol. 97, No. 3, pages 453–470.
- Nelson, R. R. and Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press., Cambridge.
- Nonaka, I., Toyama, R., and Nagata, A. (2000). A Firm as a Knowledge-Creating Entity: New Perspective on the Theory of a Firm. *Industrial and Corporate Change*, Vol. 9, No. 1, pages 1–20.
- Polanyi, M. (1958). *Personal Knowledge: Towards a Post-Critical Philosophy*. Routledge and Kegan Paul, London.
- Polanyi, M. (1966). *The Tacit Dimension*. Reprinted 1983 by Peter Smith, Gloucester.
- Roberts, J. (2001). The drive to codify: Implications for the knowledge-based economy. *Prometheus*, Vol. 9, No. 2, pages 99–115.
- Sandler, T. (1975), Pareto Optimality, Pure Public Goods, Impure Public Goods and Multiregional Spillovers. *Scottish Journal of Political Economy*, Vol. 22(1), 25-38.

- Saviotti, P. P. (1998). On the dynamics of appropriability, of tacit and of codified knowledge. *Research Policy*, Vol. 26, No. 7-8, pages 843–856.
- Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, Vol. 15, No. 6, pages 285–305.
- Winter, S.G. (1987). Knowledge and Competence as Strategic Assets. In: Teece, D.J. (ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal*. Ballinger, Cambridge, 159-184.
- Zack, M. H. (1999). Managing codified knowledge. *Knowledge Management and Information Technologies*, Vol. 40, No. 4, pages 45–58.