JOURNAL OF ECONOMIC SURVEYS

doi: 10.1111/joes.12052

ECONOMIC ANALYSIS OF KNOWLEDGE: THE HISTORY OF THOUGHT AND THE CENTRAL THEMES

Samuli Leppälä

Cardiff University

Abstract. Following the development of knowledge economies, there has been a rapid expansion of economic analysis of knowledge, both in the context of technological knowledge in particular and decision theory in general. This paper surveys this literature by identifying the main themes and contributions, and outlines the future prospects of the discipline. The wide scope of knowledge-related questions in terms of applicability and alternative approaches has led to the fragmentation of research. Nonetheless, one can identify an enduring quest for analyzing various aspects of the generation, dissemination and use of knowledge in the economy.

Keywords. Belief; Innovation; Information; Knowledge; Technological Change; Uncertainty

1. The Economics of Knowledge as an Original Discipline

The economics of knowledge studies the "role of knowledge in social systems, both as a product of the past and as a determinant of the future," wrote Boulding (1966, p. 1), who was apparently the first to use the name of this subdiscipline of economics. After that the term appeared rather irregularly in the economic literature, but in the early 21st century two books bearing the term in their title were published (Foray, 2004; Andersson and Beckmann, 2009) and it also reappeared in academic journal articles (e.g., Ancori *et al.*, 2000; Antonelli, 2003b; Lundvall, 2004). Similarly, the recent books by Warsh (2007) and Hardin (2009), and the handbook edited by Arena *et al.* (2012) illustrate the growing interest in this path of research.

Indeed, it seems to be a regular trend that economic questions concerning knowledge, its production, sharing and use, disappear from sight for a while only to surface later again. A reason, perhaps, is that in economics these are perceived as such grand questions and themes with no clear or established way to approach them. Foray (2004) notes that the economists' and other social scientists' interest in knowledge grew with the emergence of the so-called knowledge-based economies. While the causes and consequences of technological change had received attention before, by the late 20th century these issues had become increasingly important.

Boulding (1966) names F.A. Hayek, Fritz Machlup, T.E. Schultz, and Fred Harbison as the members of the small club of economists who took the importance of knowledge seriously. In addition to them, Foray sees Adam Smith, Karl Marx, and Joseph Schumpeter as the historical figures behind the discipline, and includes Herbert Simon and Kenneth Arrow among the unquestionable latter-day pioneers. As the works of these authors suggest, the early foundations of the discipline are in diverse paths of research. By now, however, Foray (2004) argues that the economics of knowledge has been finally established as an original

discipline. The purpose of this survey is to examine the intellectual origins and defining characteristics of this discipline.

To specify the scope of the discipline, Foray lays out two views. The narrow view of the scope of the economics of knowledge includes research, education, impacts on growth, learning and competences. In addition to these, the broad view also includes the economics of information, which studies change, ignorance, uncertainty, and risk; the role of expectations, the role of prices, and decision theory in general. It is unclear whether the economics of information should be included, being a well-recognized discipline on its own. Nonetheless, the topics of the narrow view and those of economics of information are largely intertwined and in the past little distinction was drawn between the two. An example is the book edited by Lamberton (1971), titled *Economics of Information and Knowledge*, which contains the seminal writings of the time addressing a range of topics from search for information and information networks to research activities and the patent system.

Unlike Foray, Andersson and Beckmann (2009) do not give a detailed account of the scope of the economics of knowledge. Judging by the contents of their book, however, the economics of knowledge includes, at the very least, the production of knowledge (both research and education), its use and diffusion, as well as the macroeconomic consequences of growth and social sharing of knowledge. They do note that before Machlup, knowledge surfaced in many discussions, many times disguised by terms such as human capital, technology, and innovation, but that only he had a broader and more concrete view of the discipline. Boulding (1966) considers the scope of the economics of knowledge in similarly broad terms. He remarks that three neglected areas calling for more research in this respect are the theories of the market, development, and decision making.

In its broadest sense, the economics of knowledge is very multifaceted. However, does that make the discipline too broad to be considered as a uniform body of economic research? Indeed, the apparent fragmentation is the basis of Mirowski's (2009) thesis, diagonally opposite to Foray's, that "there is (as yet) no such thing as an economics of knowledge." This combination of growing interest and the lack of conformity is the main motivation behind this survey. As such, we proceed forward with this broader view of the economics of knowledge while keeping the discussed reservations of its scope and existence in mind.

While most aspects of knowledge are microeconomic by their nature, the macroeconomic dimension of knowledge is present in both Foray (2004) and Andersson and Beckmann (2009). Indeed, Lamberton (1971) in his introduction to the edited volume saw the discipline bridging the gap between micro- and macroeconomics. On one hand, the microeconomics of knowledge can provide part of an explanation for the economic fluctuations that we observe in the macroeconomy. On the other hand, the creation and diffusion of new technologies, in particular, result in economic growth, which is a fundamental premise of the endogenous growth theory (Romer, 1990). Hence, while this survey mostly concerns the microeconomics of knowledge regarding its generation, dissemination and use, it is good to bear in mind that these are not interesting and relevant questions for their own sake only, but have implications for macroeconomic issues as well (David and Foray, 2002; Braman, 2006).

Another important aspect of the economics of knowledge is that it is different from most of the other subfields of economics that are more context specific. While many studies have been made on the so-called knowledge industries, information and knowledge are an integral part of the whole economic analysis itself (Lamberton, 1971; Stiglitz, 1985). Perhaps the best way to describe the economics of knowledge is, then, an "approach" that analyses any given economic phenomenon from the point of view of knowledge.

As Boulding (1966) noted, a fundamental difficulty in defining the economics of knowledge is that neither of these concepts has a simple, commonly agreed definition. Since ancient Greek philosophers, epistemology has tried to address what constitutes knowledge and, not surprisingly, there is no agreed definition among economists. We will come back to this issue later in this survey. As a working definition, we use the standard epistemological definition of "justified true belief." Without going into the particularities at this point, it means that we are interested in the contents of the human mind regarding

the facts about the world outside (i.e., propositional knowledge). This approach lets us define our scope further leaving aside skills or know-how, to the extent they are not beliefs themselves, and information embedded goods, such as computer software, being external to the human mind. Information we take to postulate communicated knowledge and beliefs.

Defining economics is equally difficult and various definitions have been offered, and later contested; some sticking longer than the others. Notwithstanding its apparent crudeness, let us settle for the idea that economics studies production, exchange, distribution and consumption, and how incentives and institutions affect these activities. The economics of knowledge can, therefore, be defined as a study of incentives and institutions in the generation, dissemination, and use of knowledge.

Regarding a further partition of knowledge, Machlup (1962) lists five different types: practical, intellectual, pastime, religious, and unwanted knowledge. For our purposes, however, a category of two types of knowledge helps us to frame the history of thought in the discipline: technological knowledge and market knowledge. A similar division was first proposed by Richardson (1960). Technological knowledge refers to production possibilities regarding the development of new products or services or more efficient production of the existing ones. Scientific knowledge, and its generation, dissemination and use, is a part of the same phenomenon, as in economic literature it is usually considered as the progenitor of technological knowledge (see, Mokyr, 2002, p. 34). Market knowledge, on the other hand, concerns the decision-making environment at large. It includes knowledge about available resources, preferences, rival products, product qualities, and the actions and beliefs of market participants.

These two types of knowledge are invoked in explaining different phenomena. Technological knowledge concerns technological development and subsequent economic growth. Market knowledge concerns decision-making and subsequent market coordination (or discoordination). Section 2 reviews the different but overlapping histories behind the two areas of research. The survey is inevitably selective, but attempts to illustrate both the combining factors and the fragmentation of the literature. While much research is confined to specific topics, there is a wider perspective of economic analysis of knowledge in the background. Section 3 addresses the main issues in this respect. Finally, section 4 concludes by appraising the development of the economics of knowledge into a separate discipline and its future prospects.

2. On the History of Economic Analysis of Knowledge

To write a complete bibliography of the economics of knowledge is next to impossible, since the majority of prolific economists have written something on the topic. At the best, then, what can be offered is a brief review of the central ideas and approaches, and the authors behind them. First, we review the developments in the economics of technological knowledge and after that regarding market knowledge, as these studies have, to some extent, followed their different paths (see, Hirshleifer, 1973). Along the way, however, we will begin to see how these paths are often intertwined.

2.1 *Invention, Innovation, and Technological Change*

Most histories of economic thought begin with Adam Smith; so does this. While Smith (1776) did not extensively discuss technological knowledge, it was included in the benefits of the division of labor as he saw them: specialization made individuals develop inventions, new ways to make their work more efficient. In the 20th century, this idea of "learning-by-doing," that is, how people accumulate (technological) knowledge as a by-product of their work and specialization, surfaces again (Arrow, 1962a).

However, it took a while before technological knowledge inspired further discussion among economists, which is perhaps surprising considering the ongoing process of industrialization during the 19th century.

Mostly the issue came up in the discussions concerning whether technological change would be able to undo the effects of decreasing returns (Warsh, 2007). While the Marginal Revolution was a major event in the history of economic thought, Menger, Walras and Jevons were more interested in the demand side of the economy and the connection between value and utility. The next to touch upon the topic of technological knowledge, was Alfred Marshall.

In his seminal work, *The Principles of Economics*, Marshall (1890) addressed the issue of why some industries colocate in particular places. Besides the advantages provided by the natural or economic conditions of a place, Marshall noted that new inventions tended to spread more easily among nearby firms. Knowledge spillovers, as they were dubbed by later economists and economic geographers, were a source of external economies and thus a cause of industrial agglomeration. Important for Marshall was the dissemination of technological knowledge and, to a lesser extent, how this process generated new knowledge when "a new idea [. . .] is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas" (IV.X.7). This is not restricted to separate firms, however. The rise of the factory is in part explained by the need to facilitate and improve the generation, dissemination, and use of knowledge within a firm (Mokyr, 2002, 140–142).

Pigou (1920) took Marshall's idea of external economies further by developing the concepts of negative and positive externalities. Both became viewed as sources of market failure, negative externalities being uncompensated nuisances or damages to others and their property. Positive externalities were, accordingly, uncompensated benefits, the most important example of which was scientific research (Pigou, 1920, II.IX.11). For the first time the generation of scientific and technological knowledge was argued to possess a problem for the market economy, although Rae (1834) among others had earlier argued for the government funding of research and development. A heated debate regarding the concept of externality and the feasibility of government intervention continued for many decades, but its scope extended beyond R&D activities (e.g., Demsetz, 1969).

Meanwhile, another idea regarding technological change was put forward by Schumpeter (1942), who argued that the capitalist economy was repeatedly transformed by a process called creative destruction. Its catalyst was entrepreneurs who constantly developed new innovations. Interestingly, Schumpeter makes a link from technological knowledge to market knowledge by arguing that the fundamental characteristic of creative destruction is that the development of new technologies makes some others obsolete. Therefore, it necessitates a restructuring of much of the economy and acts as a disequilibriating force. Initially, Schumpeter's argument seems not to have gained much attention as he did not offer a detailed account of technological change, but later scholars of entrepreneurship and innovation regard him highly as he presented technological change as endogenous to the economy: something that economists can study and explain rather than take as given.

As mentioned earlier, the most prolific economist studying technological knowledge and the economics of knowledge in general was Fritz Machlup. Machlup (1962) offered taxonomies on the types of knowledge and of knowledge industries, occupations and services, including research and development, media, and education. Furthermore, he studied the knowledge industries in terms of GDP and occupational structure in order to demonstrate their importance in the modern economy. Arguably, Machlup was successful in popularizing the concept of the information society. He set out to write a series of ten volumes collectively called *Knowledge: Its Creation, Distribution, and Economic Significance*, but only three of these were published before his death. As is apparent, the scope of topics touched by Machlup is enormous and perhaps for this reason he was unable to establish a direct following among economists, since there was no clear research agenda to pursue. Many of Machlup's ideas have stuck, however, as has his (Machlup, 1980) stock and flow distinction between knowledge (stock) and information (flow).

To return to positive externalities of R&D, several papers using the Pigouvian framework appeared roughly at the same time. Particularly, Nelson (1959) and Arrow (1962b) were successful in cementing the view that the free market was unable to provide sufficient incentives for research investments. The

proposed solutions to the underinvestment problem were the patent system (Usher, 1964) and government funding of research (Arrow, 1962b).

The costs and benefits of the patent system had been debated since its introduction (Machlup and Penrose, 1950). Criticism emerged also later on (e.g., Plant, 1934) as did comparisons between alternative reward mechanisms (Wright, 1983). Most research on R&D activities, however, took intellectual property rights as given. As such, studies on invention without intellectual property are largely a more recent development (e.g., Hellwig and Irmen, 2001; Boldrin and Levine, 2008). Foray (2004) argues that the consensus, which was reached about 20 years ago, on the desirability of the patent system for innovation and growth is now lost.

According to Arrow (1962b), the inappropriability of technological knowledge created positive externalities as the inventor was unable to capture all the benefits of his invention. Later in public goods literature (Musgrave and Musgrave, 1973), this feature became known as nonexcludability, meaning that it was impossible to exclude other users (of knowledge), whether they had contributed to the good's provision or not. Another characteristic of public goods, nonrivalness, is equally important in case of knowledge, since the same knowledge can be used both by infinite number of people and infinitely.

The (partial) public good nature of technological knowledge is also an important characteristic behind the recent growth theories. Technological and scientific knowledge was the engine of growth behind the neoclassical growth theory (Solow, 1956), but the growth of knowledge was itself exogenous and not explained by the model. The endogenous growth theory (Romer, 1990) attempted to fix this particular feature by putting knowledge production inside the model; the growth of knowledge was now a fundamentally economic process. Here, knowledge was partially excludable: the inventor was able to capture enough benefits to make the research worthwhile, but not all of them, which resulted in economywide growth due to the externalities. In Warsh's (2007) story the endogenous growth theory is the culmination of the study of the increasing returns of knowledge, which was started by Adam Smith, and finally made the economics of knowledge come into focus.

Our story does not stop there, however. Besides inappropriability, Arrow (1962b) identified other complications for knowledge production: increasing returns and uncertainty. Increasing returns meant that knowledge production and its effects on industries would be likely to result in monopolies. A similar link between imperfect competition and innovation had been earlier made by Schumpeter (1942). The uncertainty in decision-making would later become important in the studies in the economics of information, as the presence of it implied the possibility and importance of information (Arrow, 2009). Besides these supply-side issues, the demand for information seemed problematic to Arrow. Before any particular information is disclosed, the value of information is not known to the buyer, and after disclosure there is no need to buy it anymore. As a consequence, the informed agent may be required to gain control over productive assets (Rabin, 1993). Later literature dubbed this discovery as "Arrow's information paradox," which provided another rationale for intellectual property rights in markets for information. Other ways to overcome the paradox are discussed in Anton and Yao (2005).

A discussion of the economics of intellectual property rights would take us too far off the main track, but one line of research in that regard is worth pointing out. How should intellectual properties be allocated when much research seems to build upon past discoveries and in turn provide opportunities for further discoveries? This phenomenon of "standing on the shoulders of giants" became to interest scholars studying the optimal patent breadth, the optimal division of profit between inventors, and the antitrust issues in research activities (e.g., Scotchmer, 1991; Hopenhayn *et al.*, 2006). The idea of cumulative research or sequential innovation, an issue already noted by Marshall, has gained deserved interest.

A field that gave a more direct recognition to Marshall was the geography of innovation. The field took knowledge spillovers as the central explaining factor of why most innovative activities took place in large cities. A seminal paper in this field was Glaeser *et al.* (1992), who distinguished between three

different perspectives: (1) MAR spillovers, referred to Alfred Marshall's insight on external economies, Kenneth Arrow's learning-by-doing and Paul Romer's endogenous growth theory; (2) Porter spillovers, named for management scholar Michael Porter; and finally (3) Jacobs spillovers, for urban theorist Jane Jacobs. The first two approaches stress spillovers within a sector (intraindustrial spillovers) and the importance of geographical economic specialization, whereas Jacobs spillovers occur between sectors (interindustrial spillovers) and are therefore more abundant in a diversified local economy. In addition, the MAR perspective favors local monopolies, whereas the other two see strong local competition as a better incubator of innovative behavior. That monopolies were more likely to come up with new innovations was also Schumpeter's (1942) view. The impact of market structure on innovation was later addressed in the industrial organization literature (e.g., Loury, 1979; Dasgupta and Stiglitz, 1980; Aghion *et al.*, 2005). Other factors conducive to innovation have been studied in the field of economics of innovation (see, Antonelli, 2003a; Sena, 2004). A central feature is the studied two-way causation between technology and industry. The generation of technological knowledge and its effects were no longer studied in isolation and hence the legacy of Schumpeter was reanimated (see, Aghion, 2002).

Connected to Schumpeter's legacy was also the idea of general purpose technologies. The concept was introduced by Bresnahan and Trajtenberg (1995) who indicated that throughout the history of technology there had been critical inventions, such as steam power, electricity, laser, and computers, that had a large impact on a wide set of industries. These radical innovations were what characterized creative destruction.

While it is natural that technological knowledge, as a determinant of production functions, has intrigued economists, some have also studied basic scientific research. The new economics of science (Dasgupta and David, 1994) uses game-theoretic models of incomplete information to synthesize Arrow and Nelson's approach with a functional analysis of the institutional structures of science. The studies regarding truth-seeking activities of self-interested scientists have been labeled as the economics of scientific knowledge (Hands, 2001; Ferreira and Zamora-Bonilla, 2006). Its niche was created with the help of the sociology of scientific knowledge. Whereas the philosophy of science assumed that the truth-seeking behavior of scientists generates truthful scientific knowledge, sociologists remarked that the argument fails because scientists are motivated by many other things besides veracity. However, private vices can also yield public virtues, as is many times the case in economics. The outcome depends on the institutions of science and the incentives they impose upon scientists. Yet, the only relevant issue is not the generation of scientific knowledge but also its dissemination in the society. The studies on the popular knowledge of science asks the question when and under what circumstances ordinary people can trust the opinion of experts, such as scientists (Hardin, 2009). Credibility of information in communication between experts and laymen has recently been addressed in the strategic information transmission literature (e.g., Krishna and Morgan, 2001). Once again, while a sustained economic analysis on these issues is lacking, we can identify some predecessors of economics of scientific research and the organization of science, such as Tullock (1966).

Hopefully at this point the reader begins to see connections between technological knowledge and market knowledge, the latter being discussed next in more detail. Before going there, however, two of such connections should be highlighted. First, Schumpeter defined innovation as a commercial application of an invention and the driving force of creative destruction was not the scientist or the engineer, but the entrepreneur. To exploit an invention in a commercially successful way one, of course, needs relevant knowledge of the market.

Second and related to the first point, the knowledge of new technologies is not automatically disseminated and implemented. New technological knowledge is not sufficient for economic growth. This point is well made by Rosenberg and Birdzell (1986), who illustrate how many important technologies were originally developed outside the Western world, but in there they finally flourished and brought prosperity. Once again, institutions matter, also for technological change. The sudden realization of the interconnectivity of these issues is revealed by the fact that books, such as North (1990), Nelson and Winter (1982), and Rosenberg and Birdzell (1986), were suddenly on the reading lists of micro- and macroeconomists alike (Warsh, 2007, 315).

2.2 *Decision-making, Uncertainty, and Market Coordination*

Market knowledge can be generated through learning by trial-and-error, deliberate search or spontaneous discovery. It can be disseminated or transferred from an individual to another in various ways and ultimately it becomes used in decision-making at the individual or a more aggregate level. Most of the studies concerned with these issues have adopted the term of the economics of information (or information economics), though others have deliberately avoided that. As can be expected, however, these issues have a longer history in the economic thought than any specific subfield as such.

For a long time, knowledge played little if any role in the theory of choice. Economists assumed, explicitly or not, that all the agents in the economy had perfect knowledge, an assumption which single-handedly brushed aside all the possible issues related to knowledge. Surprisingly perhaps, the issue of market knowledge did not first arise in microeconomic theory, but in the debate concerning the feasibility of socialism.

Hayek (1945) joined the socialist calculation debate (see, Lavoie, 1985) with a question: can the central planner know all the things required to plan the economy efficiently? Hayek's answer was negative, because the required knowledge was dispersed in the economy, held by each individual and not possible to aggregate. Earlier Hayek (1937) had argued that Smith's division of labor implied a division of knowledge: each individual knew different things, more about the particular circumstances of their time and place. Hayek also noted that the whole concept of equilibrium in economics has much to do with the assumptions on knowledge. As Richardson (1960, 44) skillfully articulated, "In order to have an equilibrium, each individual has to be as well off as he believes he can make himself and he must be able to carry out his plans without his beliefs being contradicted by his experience."

Hayek (1945) argued that in the free market dispersed knowledge was disseminated through the price system, although prices do not transfer knowledge from one individual to another *per se* but act as knowledge surrogates. Interestingly, Hayek was later accused of not addressing the issue of (technological) knowledge production (Hirshleifer, 1973; Dasgupta, 1980). Hayek was not the clear winner of the debate initially, but the fall of the Soviet communism has been later taken as the final proof that Hayek was right. Nevertheless, it took a while before economists started to analyze the informational role of the price system.

In the meanwhile, two papers were published that apparently used the term of the economics of information for the first time. The first was Marschak (1960), which attempted to address some ambiguities concerning the value, amount, and cost of information. The more famous one, however, is Stigler (1961). Together with Machlup (1962), this paper is often considered as the seminal contribution to the emergence of the economics of knowledge (and information). Stigler's main contribution was to analyze the search for information from the standard economic point of view: each individual would look for new information until the marginal cost and benefit of the search would be equal. Any lack of information could then be contributed to search costs, and hence any ignorance would be rational. Regarding the later theoretical developments, Alchian and Demsetz (1972) argued that the consequences of asymmetric information did not imply a market failure but were rational responses to specific information costs.

The particular type of information studied by Stigler (1961) was information on prices. When the prices of a homogeneous product were unknown, the buyer would visit different sellers until he would find a price that satisfies his optimization problem. In contrast to Hayek (1945), the informational role of prices was quite different. This role was also addressed by Grossman and Stiglitz (1980). They found Hayek's argument faulty, because if information acquisition was costly and market prices revealed all the acquired information there was no private return for this costly activity. Knowledge of the prices was public good with the usual problems of efficient provision. Hence, either informationally efficient markets were impossible or information was free, in which case it possessed no problem in the first place, they concluded. A direct comparison between Hayek, and Grossman and Stiglitz is difficult, however, as they come from very different schools of thought and time periods within economics (see,

Boettke, 1997). Nevertheless, a contributing factor for these opposing conclusions can be found in conceptual differences regarding knowledge and information (Zappia, 1996). Furthermore, the role of knowledge and beliefs in the state of equilibrium as compared to the process of reaching it is very different. In the former, all beliefs must be true given the model and there is nothing more that can be learned.

Much of the economics of information which was done in the 20th century was concerned with imperfect knowledge, which then implied uncertainty. Many of these studies, however, studied choices under risk, rather than uncertainty, to use the famous dichotomy of Knight (1921). According to Knight, when faced with risk, the individual does not know the final outcome but nevertheless knows all the possible outcomes and the probabilities by which each will materialize. When faced with (genuine) uncertainty, however, the individual does not know the finite set of outcomes and his knowledge is thus in an important sense unstructured. For Knight, uncertainty was the source of entrepreneurial profit and furthermore the more interesting feature in economic activity. Due to the relative ease with which it could be modeled mathematically, it was mostly risk in Knight's terminology that was applied in economics, however. Later it became Shackle's (1972) task to try to convince the profession that uncertainty in decision-making should be taken more seriously in economic analysis as the meaning of a choice implied more than a technical calculation problem. As noted by Arrow (1962b) already, uncertainty is, of course, prevalent in decisions concerning R&D investments.

Information economics largely traveled its own path (see, Stiglitz, 1985, 2002; Braman, 2006; Arrow, 2009). The final breakthrough of the field was due to the analysis of asymmetric information, where one party knew more about the object of the contract than the other, which was acknowledged by the Nobel Prize in Economics shared by Akerlof, Spence and Stiglitz in 2001. Akerlof (1970) used the market for used cars as an example to demonstrate that when the seller knew the exact quality of his car and the buyer knew only the average quality of the cars in the market, it would drive all the good cars out of the market. The same analysis was soon extended to other markets beyond used cars as similar informational asymmetries seemed prevalent in many occasions. Note that this framework departs relevantly from Hayek's view of dispersed knowledge, according to which one is more likely to know the particularities that are familiar to him, such as a car he has inspected, rather than the general structure of the market, like the quality distribution of all cars.

The information asymmetry could be decreased between the parties and two of such methods were signaling and screening. In Spence's (1973) model the competent job seeker could signal his higher productivity to future employers by formal education. Education as such did not affect the productivity, but it was a reliable signal because it was less costly to take for those with higher productivity and hence education would reveal their innate talent. Through screening, on the other hand, the employer established a mechanism that would reveal the hidden information to him. By offering a menu of choices the employer can identify the workers' productivity (Stiglitz, 1975). In these mechanisms, information is induced from observing actions, which indeed is an important source for knowledge dissemination and indirectly what the idea of knowledge spillover implies.

Noticeably, the above communication mechanisms need to be costly, which guarantees that any sent message is a true statement of a fact. Conventional communication, however, was considered as mere "cheap talk" conveying the idea that it is both free and (therefore) meaningless. In the models of asymmetric information, nothing prevents communication as such, but the problem is that the disadvantaged parties would report the same information as the advantaged ones and nothing reveals who is telling the truth. In this regard, already Hirshleifer (1973) noted that manipulation of information is one of the central themes of the economics of information. Later, however, a small but growing literature studying where the argument of uninformative communication holds or not has emerged (e.g., Crawford and Sobel, 1982; Farrell and Rabin, 1996; Chakraborty and Harbaugh, 2010). The central result is that when signaling is costless and messages cannot be verified, the informativeness of a message depends on how similar the agents' goals are. In other words, the dissemination of knowledge through conventional communication

depends likewise on incentives. Sometimes it can improve the coordination of actions (Ellingsen and Östling, 2010).

The assumption of a perfectly rational decision-maker who was capable of optimizing even in the presence of risk was ultimately contested by Herbert Simon. According to Simon (1955), the actual decision-making in firms is characterized by "satisficing" rather than by optimization. Following different heuristics that they have found adequate in the past, individuals were "boundedly rational." Simon received the Nobel Prize in Economics in 1978 and his work continues most profoundly in behavioral economics and behavioral finance. However, while also concerned with knowledge and learning, these put more emphasis on the cognitive limitations of using the available information efficiently rather than the lack or imperfection of knowledge itself.

Simon's work has had an impact on management scholars and organization theorists as well. This is true particularly in the field of knowledge management (e.g., Nonaka and Takeuchi, 1995), which is concerned with the creation, dissemination, and use of knowledge in the firm. Interestingly, this field could benefit from the economists' work discussed here, such as Hayek's work on the use of knowledge in a (de)centralized society, and these paths have not been fully explored yet (see, however, Foss, 1999). In addition, giving a nod to Hayek and Smith, Becker and Murphy (1992) argue that the coordination of specialized workers becomes increasingly costly and may be the true limit to the division of labor. The same issue would seem applicable to universities, and thus worth exploring by the economics of scientific knowledge. Firms do not manage knowledge only internally, however, but also in relation to the market. Hence, the rich variety of problems related to knowledge is a determinant of the boundaries of a firm (Holmström and Roberts, 1998; Kling, 2010, pp. 39–48). Despite its importance, however, neither economists nor management scholars have been able to provide a satisfactory theory of the knowledge firm (Walker, 2010).

So far we have discussed the economists' rationality assumption in passing, but not its connection with knowledge. Latsis (1972) argued that the rationality principle is void of describing the actual decision-making process if the choices are fully determined by the objective conditions. Instead of the objective conditions (and preferences) determining the choice, it is beliefs concerning the conditions that enter into the decision-making process. Bicchieri (1993) made later a similar point by arguing that it might be useful to separate the notions of "practical rationality" and "epistemic rationality."

Practical rationality means that an agent chooses optimally, in the light of her desires and beliefs. If S desires q and believes that p is the best way to enable q, she is practically rational by choosing p. Thus, practical rationality says nothing about the content of beliefs, only that the agent acts accordingly. Epistemic rationality, on the other hand, is concerned with the content of those beliefs. It refers to beliefs by saying that rational beliefs are such that (1) they are internally consistent; and (2) they are formed appropriately in the light of available evidence (Bicchieri, 1993, p. 2). Bicchieri (1993, 13) admits that it is a legitimate question whether the double rationality requirement is necessary for explaining and predicting individual behavior, since one could do without epistemic rationality by assuming perfect knowledge. Her conclusion is nevertheless that perfect knowledge is neither the most common nor the most interesting case.

During recent decades, game theory has moved to the forefront in studying knowledge in economic decision-making. To a large extent, this development is due to the fact that in strategic interaction assumptions on knowledge are especially critical, particularly when considering the justification for a particular equilibrium or studying the assumption of common knowledge and its implications. For game theory, it is very relevant what is assumed about the agents' knowledge of the environment and each other. Surveys on these developments are provided by Dekel and Gul (1997), Battigalli and Bonanno (1999), and Samuelson (2004). In particular, game theory has proceeded to analyze knowledge of a higher order, that is, knowing about knowledge that you yourself and others have (e.g., Hellwig and Veldkamp, 2009).

Recent developments in the economics of market knowledge include the studies of collective decision-making and the use of knowledge. The received interest is much due to the Internet, which has enabled new

ways to create, disseminate, and use knowledge collectively, such as Wikipedia (for detailed examples, see Sunstein, 2006b). Prediction markets are similarly interesting phenomenon due to their use of dispersed knowledge in very Hayekian manner (Wolfers and Zitzewitz, 2004; Heath, 2007). Sunstein's (2006a) work on how deliberating groups often converge on falsehood rather than truth and why they are outperformed by prediction markets takes an important step in this direction. The wisdom of crowds, that is, how individuals can make better decisions collectively than even the brightest of them alone, is very interesting from the point of view of the organization of economic activity. Lastly, as the recent book by Hardin (2009) demonstrates, economic analysis can be extended to a very wide variety of knowledge and beliefs, such as political knowledge, religious beliefs, cultural knowledge, and moral knowledge.

While known to been in disagreement on many other issues, Stiglitz (2000) gives Hayek full credit for pointing out how important the questions on knowledge are for economics. Stiglitz (1985) concurs that informational considerations are a foundational part of economic analysis and notes that these have had both a negative and positive impact on economics. The negative impact is that some things that were once taken for granted have been now contested and need to be reconsidered, whereas the positive side is that completely new venues of research are now open to new generations of economists. The key questions of the field according to Stiglitz (2000, p. 1469 and 1471) are the following: "how the economy adapts to new information, creates new knowledge, and how that knowledge is disseminated, absorbed, and used throughout the economy" and "how and how well organizations and societies absorb new information, learn, adapt their behavior, and even their structures; and how different economic and organizational designs affect the ability to create, transmit, absorb, and use knowledge and information."

As the above quotes demonstrate, Stiglitz's view of the domain of the economics of information is very broad. Indeed, it is very similar to Foray's (2004) broad view of the economics of knowledge. Stiglitz (1985, 2002) also explicitly includes technology and R&D in the domain of the economics of information. A strict separation between the economics of knowledge and information would then seem at least equally arbitrary as their integration. Should we then simply use the economics of information as the principal category of the discipline? While nothing prevents it, "knowledge" seems a more natural choice. (The exchange of) information is an integral part of economic analysis of knowledge, but without the concept of knowledge, the analysis misses some key aspects that should be considered. Among others, this issue will be elaborated in the next section.

3. Some Central Issues in the Economics of Knowledge

Several central issues regarding how economists have traditionally addressed knowledge emerge from the literature, some of which have been criticized of narrowness. For example, Amin and Cohendet (2004) note that knowledge has been largely considered codified, individual, and action or context independent, which leads them to seek alternative approaches from other disciplines. While interdisciplinary perspectives are welcome, this has also contributed to the fragmentation of the economics of knowledge. As such, reconsidering and revising the existing economic analyses of knowledge could be a way forward. This section addresses the contemporary work and what could be done in the future with this regard. A central challenge is to broaden the perspective while retaining the analytical tractability.

3.1 *Knowledge as an Input and Output of Creative Activities*

Machlup (1962) was the first to explicitly study knowledge as an economic good. According to him, knowledge can be an investment, intermediate, or consumption good. Since Pigou (1920), particularly scientific and technological knowledge have also been regarded, more or less, as a public good and a source of positive externalities. Nonrivalry of knowledge implies that its use is unlimited in principle (both in time and between users) and nonexcludability that its use cannot be limited in practice. The standard

argument in the literature is that without excludability there is insufficient private gain in knowledge investments, which must be remedied through intellectual property rights or government subsidies (e.g., Arrow, 1962b, 1996). Some argue that the underinvestment problem is less severe in reality, because of partial excludability (e.g., trade secrets, R&D cooperation, and tacit knowledge).

Knowledge being both the input and output of an R&D investment leads to sequential innovation, where the generation of new technologies depends on past advances. More generally, the different phases of both market and technological knowledge processes are highly interdependent as the development of new technologies depends on competences (Amin and Cohendet, 2004, p. 15). Thus, while sometimes it is necessary to focus on the generation, diffusion or use of knowledge, the linkages between them should be remembered. For example, a research investment, itself a decision under uncertainty, depends on the following use and dissemination. Similarly, a central idea behind Jacobs spillovers is that once generated, technological knowledge is not only disseminated but that the dissemination itself can create new knowledge (Desrochers and Leppälä, 2011).

Economic development and the coordination of economic activities depend both on the use of existing knowledge and its growth. This effectively links together market knowledge, on the one hand, and technological knowledge, on the other. Efficient generation and dissemination of technological knowledge depend on market knowledge and efficient use of market knowledge depends on the existing technological knowledge. The link is the most clear in the case of firms, since they rely on the generation, dissemination, and use of both market and technological knowledge (Amin and Cohendet, 2004). Similarly, uncertainty and the required judgment are more concrete and complex there as the owners delegate a wide range of decision rights to subordinates (Foss *et al.*, 2007).

The notion of creativity, whether we talk about the inventive action, the economic application of an invention, or the entrepreneurial imagination in discovering profit opportunities, seems central in the economies of knowledge. However, as a psychological concept and process, it is unclear whether economists have much to say about it. Nevertheless, it has been long recognized that diversity, in terms of background knowledge, new ideas and modes of thought, enhances creativity (Desrochers, 2001). The formal logic behind this idea and how it successes or fails in different situations was demonstrated in Hong and Page (2001) and Page (2007). Differences in knowledge, unlike asymmetric information, can thus be a favorable factor.

Nevertheless, it is foremost the study of incentives (to generate, disseminate and use knowledge) where economists have a comparative advantage. While we are not only interested in isolated individuals, there is no direct access, however, to each other's minds, and hence knowledge can only be shared indirectly via communication or observation. As such, knowledge has an irremovable social component but can only be absorbed individually (Arrow, 1994). Furthermore, there is no collective mind that has all the knowledge that the individuals have and which is capable of efficient decision-making on their behalf (Hayek, 1945). Knowledge may in principle satisfy the criteria of public goods but whether or not and how and when it becomes common knowledge is a different question.

The issue of how and if knowledge becomes commonly shared is also present in the discussion about the informational role of the price system. The impossibility of informationally efficient markets (Grossman and Stiglitz, 1980) is ultimately framed as a public good problem: there is no private incentive for information acquisition when others are able to free-ride on it. However, the Hayekian argument is that individuals already have some local knowledge; it is only that getting direct access to the local knowledge of others that is costly (Leppälä, 2010). As a by-product of their transactions the local knowledge becomes incorporated into prices, though not completely communicated by them. In addition, the informational role of the price system also works to generate new knowledge when individuals have to adjust their beliefs according to the changing prices.

Regarding the efficient market hypothesis, according to which prices always reflect all available information, Grossman and Stiglitz were more on target. The efficient market hypothesis has also received counter-evidence from behavioral economists (Lo, 2008). To reconcile the hypothesis with behavioral

anomalies, however, Lo (2008) finds recent advances in evolutionary psychology and the cognitive neurosciences promising. As such, Hayek's view on the information role of prices with its cognitive foundations (Leppälä, 2010), combined with research on social learning (e.g., Manski, 2004), could provide a basis for the efficient market hypothesis as a learning process with knowledge as both its input and output.

3.2 *Knowledge Spillovers and the Geography of Innovation*

Knowledge spillovers as a generator of external but local economies have received much attention among economists and economic geographers working in the field of the geography of innovation (e.g., Glaeser *et al.*, 1992; Feldman and Audretsch, 1999). The motivation is easy to see: what keeps cities together? Why is most innovation done in cities despite the emergence of new communication technologies? The standard answer is that knowledge spillovers remain locally bounded, which provides a reason to locate near its sources (e.g., Keller, 2002; Gertler, 2003). While ICTs greatly advanced communication, innovation requires more than deliberate information transmission. Different explanations for what then keeps firms and people colocated in this respect have been provided; most of them alluding to tacit knowledge.

Knowledge spillovers are local public goods generating positive externalities. Particularly, Jacobs spillovers were seen as the driving force behind the endogenous growth theory (Lucas, 1988; Romer, 1990). Hence, these knowledge externalities would seem to be simultaneously a symptom of a market failure as well as the engine of growth and development. However, since many economic aspects of knowledge seem to entail externalities, Demsetz' (1969) call for a comparison between real institutional alternatives rather than between an existing imperfection and an ideal norm is critical.

Furthermore, it is not even perfectly clear that the knowledge spillovers studied in the contemporary literature are truly knowledge externalities (Breschi and Lissoni, 2001a). When one studies the effect of cooperation and social networks behind innovative activities, knowledge spillovers are deliberate. Patent data is also constantly used in these studies, which seems to counter the idea of externality as patents are meant to internalize social benefits. Similarly, while labor mobility between firms is argued to induce knowledge spillovers, the labor market might be quite effective in internalizing such externalities (Møen, 2005).

Behind this issue and many other obscurities regarding localized knowledge spillovers is the fact they are treated ultimately as a "black box" (Breschi and Lissoni, 2001a). While there has been much empirical research on the MAR–Porter–Jacobs controversy, for example, these studies have fallen short of proving or documenting the existence of knowledge spillovers (Beaudry and Schiffauerova, 2009). This result is largely unsurprising, since these econometric studies have approached the phenomenon by trying to find links between regional attributes (size, industrial structure, etc.) and development and growth. As a result, while knowledge spillovers supposedly explain the existence of agglomeration, the geographical agglomeration of economic activities is now taken as evidence of the existence of knowledge spillovers. As Leppälä and Desrochers (2010) suggest, any study of agglomeration economies should be approached from the individual or firm level to explain why the benefits of more specialized or diverse cities are both specific to a particular location and uninternalizable by firms or individual inventors themselves. Knowledge spillovers are undoubtedly an important phenomenon in this regard, but as Breschi and Lissoni (2001a) and Hansen (2002) suggest, it requires studies on how innovative know-how is actually created, diffused, adapted, and combined by individuals. Desrochers and Leppälä (2011) study the circumstances conducive to Jacobs spillovers, for which the interindustrial and sequential nature of innovation are characteristic.

Following the French group Proximity Dynamics, many researchers have proceeded to examine other dimensions of proximity (see, Carrincazeaux *et al.*, 2008). Boschma (2005) considers only cognitive proximity to be necessary for interactive learning and innovation, whereas the other dimensions, such

as geographical proximity, may facilitate it. While too high cognitive proximity depletes learning opportunities, also too high cognitive distance is detrimental (Nooteboom, 2000). Here, the emphasis is placed on understanding the information, however. While necessary for gaining knowledge, it is not sufficient since also the validity of information needs to be assessed. This represents another, and largely neglected, dimension of cognitive proximity, which can be further facilitated by geographical or social proximity increasing the reliability of information channels or the receiver's ability to recognize them.

3.3 *Tacit Knowledge*

Tacit knowledge is a concept that we have already mentioned several times as it appears in many areas of the economics of knowledge. The origin of the concept dates back to Polanyi (1958), who described tacit knowledge as the part of our knowing that we are unable to communicate to others. Other concepts, such as know-how (vs. know that) and procedural knowledge (vs. propositional knowledge), have been used to capture the same idea. The standard example of tacit knowledge in the literature is riding a bicycle: one is unable to convey all the knowledge required riding a bicycle and hence the other can learn it only by practicing himself. As such tacit knowledge refers largely to different kinds of skills. Interestingly enough, riding a bicycle is the example that economists and other social scientists usually give, whereas considering the claims of prevalence and importance of tacit knowledge, one would think that other examples better related to economic and social phenomena would have been deployed.

Many critics have pointed out that the seminal insight of Polanyi has been, to some extent, misrepresented (Cowan *et al.*, 2000; Breschi and Lissoni, 2001b; Brökel and Binder, 2007). For example, tacit knowledge implied that it is not only hard to convey through verbal exchange but indeed impossible. In the literature, however, tacit knowledge accounts for any reason for why some knowledge is not immediately communicated and commonly shared. Perraton and Tarrant (2007, p. 354) make an even stronger case by saying that "the concept of tacit knowledge is merely a term given to a phenomenon that the observer does not understand; as such, it has no explanatory content."

The ambiguity surrounding the tacitness of knowledge has made some suggest that the concept has become too stretched (Breschi and Lissoni, 2001b), and it certainly seems so. Others, such as Gertler (2003), however, draw the opposite conclusion that the concept was originally too limited. Making the concept too broad has at least two drawbacks, however. First, the original meaning has some merit which is lost if tacit knowledge no longer implies knowledge that is impossible to articulate. This can be important in some situations and deserves a concept of its own. Sometimes propositional and procedural knowledge can, of course, be intertwined, such as in gaining human capital through formal education. Besides learning useful skills, education provides facts, but if it was only the latter the interactive process of teaching and learning in schools and universities would seem wasteful.

Second, the broad use of tacit knowledge can cloud the true reasons behind why some knowledge resists to become widely disseminated. Cowan *et al.* (2000) raise the issue that some knowledge is not codified (or communicated), not because it is impossible to do so, but because it is not economical. This brings us back to the incentives of communication. Furthermore, as is argued in Leppälä (2012), even if something is communicated it does not necessarily imply that knowledge is transferred. Available information does not automatically translate to shared knowledge, since incentives matter when individuals attempt to assess the validity of information. We will develop this issue further in the next subsections.

3.4 *Justified True Belief*

Until now, we have evaded the discussion about what constitutes knowledge. This is indeed one of the hardest but also of the most important questions when laying out the past and future scope of the economics of knowledge as a discipline. Since Plato's *Theaetetus*, epistemologists have studied knowledge on the

basis of three conditions: S knows p if and only if S believes that p, S's belief that p is justified, and it is true that p. While there was much discussion on the nature of these conditions, the traditional definition remained unchallenged until Gettier (1963), who gave counter-examples of justified true beliefs, which yet would not count as knowledge. The basic idea behind these is that one can be justifiably believe a falsehood from which one deduces a truth, and thus one has a justified true belief but does not actually know it (Foley, 2002, p. 178).

The general problem with the traditional definition, which the counter-examples highlight, is that while fulfilled, the three conditions can be completely independent. Different strategies emerged to rule out Gettier type of problems, but none of these has proven completely satisfactory (Dancy, 1985, p. 26). However, to quote Ancori *et al.* (2000), the point here is not to solve debates of other disciplines, but to acknowledge that a given epistemological theory will affect our understanding of economic phenomena. While the Gettier counter-examples showed that the traditional definition might not be sufficient for all conceivable cases, the three conditions remain necessary. As such, justified true belief still provides a good working definition of knowledge for economists. Most relevant in this respect is that when studying knowledge economists have either ignored justification of beliefs or their truth altogether. As Faulkner and Runde (2004, p. 424) have noted, "mainstream microeconomic theory tends equate knowledge with true belief."

As said earlier, developments in game theory have induced many game theorists to study epistemic logic. Following Hintikka (1962) and epistemic logic in general, game theory studies knowledge based on five principal axioms (see, Dekel and Gul, 1997; Samuelson, 2004). Of these, the axioms of positive and negative introspection are of our main interest. The idea behind these axioms is that people are capable of self-reflection: if they know something they are able to reflect that they know this (positive introspection); if on the other-hand they do not know something, they know that they do not (negative introspection). While these axioms have fallen out of favor among philosophers (Lenzen, 1978), their position in game theory seems very strong.

Hayek (1937) argued that in economic models it ought to be kept carefully apart what the observing economist knows and what the agents whose behavior is under examination are supposed to know. In these models, however, the agents know exactly the same as the economists who build the model (Faulkner and Runde, 2004, p. 433). This approach blurs the distinction between "knowledge of the economy's structure" and "knowledge within the structure" (Bellante and Garrison, 1988, p. 213).

Due to positive introspection, agents are always aware of what they know. It can be reasonable to restrict ourselves to models in which agents have only true beliefs; otherwise the economists could introduce whatever false beliefs are needed to derive the sought conclusions. However, it is a much stricter assumption if the agents in the model are aware that their beliefs are necessarily true. Particularly, when this extends over interacting agents and their beliefs about the beliefs of others and so on, we arrive at situations where, for example, the agents are unable to "agree that they disagree" (Aumann, 1976). Aumann's (1976) result is, however, less striking when one sees that it is already an implicit premise of the argument (Hild *et al.*, 1999; Stalnaker, 1999). While introspection is an important part of rationality, neglecting justification leads to situations such that each agent knows with certainty that whatever beliefs other people have or whatever information they have received is always true, at least with a known probability.

Negative introspection is similarly problematic. Particular Austrian economists and others working within the tradition of Knightian uncertainty have argued that "not knowing what we do not know" is a central ingredient in decision-making and should thus not be ignored by economists (e.g., O'Driscoll and Rizzo, 1985). In the case of technological knowledge, the axiom would imply that everyone is completely aware of all the possible technologies that they do not yet know. Knightian uncertainty entails judgment regarding what beliefs, and subsequent decisions, are justified. The practical problem is, of course, that it is unclear how to model Knightian uncertainty. As such, it has been acknowledged that the standard state–space model is incompatible with analyzing unawareness, without which there is no structural uncertainty,

only risk (Dekel *et al.*, 1998). However, having created the model the economist is necessarily omniscient regarding its structure. Therefore, it seems improper if not impossible to assume anything less on the part of the agents in the model (see, however, Li, 2009). Particularly, formalizing innovation and creativity in this regard seems challenging as it involves a shift from unawareness to awareness.

Ignoring justification precludes any explanation for why beliefs would be true or not in particular situations. As North (2005, p. 99) notes, "A thorny question is just what we mean by knowledge since human decision making has, throughout history, been guided by possessed beliefs that have more often than not proven to be incorrect. Indeed the heart of this study is about the uncertainty humans face and the way they have dealt with that uncertainty. Are beliefs knowledge?"

An alternative to conflating knowledge with true belief is to ignore truth altogether. This leads North (2005, p. 17) to define knowledge as "the accumulation of regularities and patterns in the physical and human environment that result in organized explanations of aspects of those environments" without any "implication that such knowledge is 'true.'" For the same reason, Boulding (1966) prefers "image" to "knowledge," since it has no similar tendency to approach the meaning of truth. According to him, image is something that its possessor believes to be true (see, also Mokyr, 2002, p. 6).

However, the mere accumulation of beliefs, unless connected to truth, is not unambiguously desirable. Usually, we regard only true beliefs beneficial to productivity, creativity or the well-being of individuals, and as the objective of learning. As such, our epistemic goals are to acquire as many true beliefs as possible and as few false beliefs as possible, and these are fundamentally connected with our pragmatic goals.

Acknowledging the possibility of false beliefs requires a theory of justification. Only then can we assume that over the course of time people do have a greater tendency to acquire true beliefs and revise their belief sets to discard false ones. Otherwise true beliefs would be a mere happy accident. Furthermore, Boland (1992, p. 124) has argued that the existence of false beliefs should have an important role in explaining how we arrive at true beliefs. The issue that truth cannot be directly verified is not a reason to abandon the condition, but a reason why justification is important. Assuming that all beliefs are necessarily true or disregarding the question of their veracity altogether would severely hinder our understanding of knowledge in a social world.

Indeed, economics has a potential role in social epistemology (e.g., Goldman, 1999). While belief is primarily a psychological phenomenon and truthfulness belongs to the fields of metaphysics and semantics, the central issue for epistemology is justification. While traditional epistemology only addressed the issue in case of isolated individuals, social epistemology studies knowledge and justification in social context. By studying the incentives in social interaction, the economics of knowledge can thus yield a contribution in the form of economic epistemology (see, Mäki, 2005). The issue of justification may become increasingly important as the key challenge in the contemporary society is no longer the access to information, but the trustworthiness of its content (Carlaw *et al.*, 2006). So far, however, the issue of justification has received limited interest among economists.

3.5 *Knowledge and Information*

The difference between knowledge and information, or the lack of it, has been raised from time to time in economic literature (David and Foray, 2002; Foray, 2004). For example, it has been claimed that the distinction between the concepts is what differentiates Austrian economics from the mainstream (Boettke, 2002; Metcalfe and Ramlogan, 2005), as according to the former decision-makers do not only passively react to information. While it seems unobjectionable that we "must actively interpret the information we receive, and pass judgment on its reliability and its relevance for our decision-making" (Boettke, 2002, p. 267), the ambiguity surrounding the distinction between knowledge and information and its relevance for economic analysis remains.

In 2003, *Econ Journal Watch* invited economists who work on information and knowledge to write a brief reflection on the distinction. "Symposium on Information and Knowledge in Economics" was published in the April 2005 issue and the contributors included Brian J. Loasby, Thomas Mayer, Bruce Caldwell, Israel M. Kirzner, Leland B. Yeager, Robert J. Aumann, Ken Binmore, and Kenneth Arrow. While interesting insights were offered, it became clear that no common understanding about the difference between the concepts exists. Summarily, the lines were drawn on the issue of whether gaining knowledge requires interpretation and judgment of information and whether this is a critical issue for economics. Interestingly, Binmore's (2005) main argument is the important distinction between knowledge and belief instead, but he does not show that this could be relevant to the distinction between knowledge and information as well.

In the literature, knowledge and information are many times used interchangeably. This can be seen already in the writings of Hayek and Machlup and is common to the contemporary microeconomic theory (Foray, 2004). It is easy to see why the distinction would not matter if the models assume beliefs and information to be necessarily true. Having particular information automatically implies that you know the fact conveyed by it, and a particular known fact can always be conveyed to others in the form of information. As a consequence, having knowledge and receiving information imply the same thing.

The above equality between knowledge and information can also be seen as a motivation for adopting the concept of tacit knowledge. If some knowledge cannot be codified and conveyed as information, then this can explain why it is not commonly shared. What has remained unnoticed, however, is that available information does not need to imply shared knowledge (or belief). Information and knowledge do not necessarily correspond.

Though Arrow was at the time unable to fully participate in the above mentioned symposium, he had provided a letter with the permission to publish it as correspondence regarding the symposium. In the letter Arrow (2005) explained that he cannot think of a context that would accommodate the distinction, and hence make it meaningful. Interestingly, it would seem that the information paradox provides a context that Arrow asked for. The paradox states that *ex ante* the buyer cannot know the value of particular information; it can be known only after it has been disclosed. However, the buyer has no reason to compensate the seller *ex post*.

In most cases, however, it would seem that one can describe what particular information concerns without revealing the content. Hence, the uncertainty shifts from the type of knowledge to the issue whether the other party actually has it, since it has not been yet revealed. This brings us to the correspondence between information and knowledge and the issue of justification. As is argued in Leppälä (2012), we can divide the issue of correspondence into two parts: capability and reliability. Capability concerns the issue whether the sender (or seller) has a true belief, that is, the belief corresponds to a fact, and reliability whether the conveyed information would correspond to that belief. Only when both capability and reliability are in place, also the information corresponds to a fact. Capability and reliability depend on the incentives of the sender and, when fulfilled, provide a justification for the receiver. As such, as long as the truthworthiness is not self-evident information and beliefs are different from knowledge.

4. From Perfect Knowledge to Quantity, Variety, and Quality: Some Concluding Thoughts

Edith Penrose (1959, p. 77) noted, that "Economists have, of course, always recognized the dominant role that increasingly knowledge plays in economic processes but have, for the most part, found the whole subject of knowledge too slippery to handle with even a moderate degree of precision [. . .]." Hence, the slow start that the economics of knowledge had cannot likely be attributed to the past economists' narrow view, but to the fact that the assumption of perfect knowledge only made theorizing so much easier. While the generation, dissemination, and use of knowledge surfaced from time to time, usually such considerations were omitted for the sake of simplicity.

It took a considerable time before the weight of that omission became noticed. In the words of Brian Loasby (1986, p. 41), "It is now becoming widely recognised that many of the central unresolved problems in economics turn on questions of knowledge." As Foray (2004) argues, it was due to the rise of knowledge economies when the issue could no longer be avoided.

The first step to proceed in microeconomic theory was to see what happens if we relax the assumption of perfect knowledge slightly. What would happen if individuals knew the structure of the economy but not some particularities of it? Hence, the perfect knowledge assumption was relaxed in terms of the quantity of available information. Economists studying research activities took similar interest in the quantity of knowledge: what are the incentives to invest in research and development? What type of institutions would provide sufficient incentives for individuals so that the socially optimal level of scientific research would be achieved?

While the issues regarding the quantity of knowledge are relevant, I would argue that now it seems that at least equally vital are variety and quality. The variety of beliefs and ideas has become increasingly recognized as the driving factor behind creativity and innovation, not only as a potential market failure. Enhanced by variety, the generation of new ideas is achieved by recombining and reconfiguring old ideas (Weitzman, 1998; Desrochers, 2001). When people with diverse background and education interact with each other, formally or informally, they constantly face better opportunities to incorporate the ideas of others into theirs and, as a result, create something new.

The variety of knowledge also implies dispersed knowledge. No longer, however, is dispersed knowledge seen only as a challenge for its efficient use but also as an opportunity. When we have suitable institutions that allow the efficient use of dispersed knowledge, we have tapped into great potential. When everyone needs not to know the same things, the variety of knowledge that the society can utilize is hugely increased. Understanding why some institutions succeed or fail in this regard is relevant in various situations considering the organization of activities and decision-making. In addition, it leads to new ways to tap into the vast knowledge base of individuals through the use of new instruments and mechanisms, such as prediction markets.

Lastly, we come to the issue of the quality of beliefs and information, which I find both the most neglected and most promising. Many special characteristics of knowledge as an economic good have, as we have observed, been discussed in the literature. However, these include nonrivalry, nonexcludability, and cumulativity of knowledge rather than quality by which I mean the truthworthiness of beliefs and information. I suspect that this is partly because "Many strands in economics have [. . .] neglected the discussions on the subject of the nature of knowledge: the field of epistemics, while discussed in philosophy and in the other social science, is ignored" (Dolfsma, 2001, p. 71). According to Stiglitz (2002), the reason for the late development of models with imperfect information (and knowledge) was that it was not obvious how to do so. Knowledge can be perfect in a single way, but be imperfect in an infinite number of ways. As is suggested here, one important way of imperfection considers the quality of knowledge, which is increasingly important when beliefs differ.

By ignoring justification, economists have taken a critical shortcut by either assuming that all beliefs are true or that the issue of veracity is not an issue at all. To understand why rational actors would be more likely to have true rather false beliefs, why some information is likely to be false or true, and how rational actors react to this uncertainty, can only be addressed by a theory of justification. Koppl (2006) has recently provided a general theory of epistemic systems, that is, the social processes generating judgments of truth and falsity, and shown how it can be applied, for example, to the analysis of torture or police forensics. Truthworthiness is not an issue only in dissemination, that is, the possibility of receiving false information, but in the generation and use of knowledge as well.

The uncertainty regarding the generation of knowledge concerns not only that an effort gives no results, but also that some result may not be correct. There cannot be growth of knowledge if the new beliefs are false. Similarly, a part of the uncertainty in decision-making comes from the fact that some beliefs on which those decisions are based might not be true. At first justification might seem like a topic of

which economics has little to say about, but on the other hand it depends on incentives as well. This revelation leads to the idea of economic epistemology, which can be useful and complementary to other approaches in a wide variety of issues and topics. This is also the reason why I prefer the term, the economics of knowledge, because ultimately it is knowledge proper that we are interested in. While some discussions concentrate on more specific issues, and there a more specific term is in place, the economics of knowledge is a useful term to convey the idea of relatedness among these issues.

While the perspectives and the approaches within the economics of knowledge as presented here only scratch the surface, it is more than evident that while they nominally address the same issues they are many times largely detached, mainly because research is problem-oriented. A contributing factor for this fragmentation of research can also be found in sociological factors, namely different scholarly communities with their traditions (Mirowski, 2009). How should we then assess Mirowski's claim of the nonexistence of the economics of knowledge? If the standard is the existence of a single, coherent tradition, and fundamental laws and theorems, as Mirowski seems to argue, we would be inclined to agree. However, another reasonable standard for the existence (instead of success, which remains to be seen) of a scholarly discipline is serious and widespread research, even if partially incoherent. Hence, an attempt to connect bits and pieces to advance our general understanding about a relevant theme, even if grand theories are still beyond the horizon. For the moment, the economics of knowledge is a dispersed research framework approaching various fronts in several ways, rather than a self-identified and uniform research agenda. Arena *et al.* (2012), (1) note that while "a large literature dedicated to the role of knowledge within economic relations" was born, "it is not certain whether the numerous contributions on these issues have contributed to a better understanding of the key questions related to the notion of knowledge in economics." Ultimately, calling it a discipline in its current state depends on how strict definition is applied. Only will time tell whether it becomes more closely knit, but the growing recognition and interest in knowledge-related issues among economists is likely to persist, making these interesting times for researchers.

The omnipresence of knowledge in economic issues is both the strength and the weakness of the economics of knowledge leading to wide applicability but also fragmentation. Due to the nature of the research object, the fundamental laws of economics of knowledge will perhaps have to wait, but the fragmentation of research will not help the development of more general models either. According to D.M. Lamberton (quoted in Braman, 2006), in 1976 information received its AEA classification and by 1984 at the latest questions in every AEA classification category were addressed from informational perspective. Today much of the research is confined to various field journals and serious efforts to synthesize this field are few. Perhaps the renewed interest in the economics of knowledge will help to get these strands of research together. Nevertheless, the way forward is from interaction to coherence and from coherence to more general theories.

Besides the apparent fragmentation, the discipline overlaps with studies in other sciences, such as philosophy, sociology, economic geography, psychology, and management. Yet I believe that the economics of knowledge has an unquestionable niche in addressing these topics. Economists have a comparative advantage addressing the incentives and institutions in the generation, dissemination, and use of knowledge. I see potential for many interesting and relevant paths of research ahead for economists interested in studying the role of knowledge in social systems, and hopefully this survey is far from the last word on the topic.

Acknowledgements

I would like to thank two anonymous referees for valuable comments on the earlier version of this paper. It was based on the introductory chapter of my doctoral dissertation (Leppälä, 2011), which was largely written in Fall 2010 during my visit at the Center for the History of Political Economy in Duke University. As such, I would also like to thank the faculty and visitors at the Center as well as those who commented on my

dissertation manuscript, most importantly my thesis pre-examiners, Panu Kalmi and Tuomas Takalo, and my official opponent, Suzanne Scotchmer, for their feedback and suggestions. Financial support from OP-Pohjola Research Foundation is gratefully acknowledged. The usual caveat applies.

References

Aghion, P. (2002) Schumpeterian growth theory and the dynamics of income inequality. *Econometrica* 70(3): 855–882.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., and Howitt, P. (2005) Competition and innovation: an inverted-U relationship. *Quarterly Journal of Economics* 120(2): 701–728.

Akerlof, G. (1970) The market for "lemons": quality uncertainty and the market mechanism. *Quarterly Journal of Economics* 84(3): 488–500.

Alchian, A. and Demsetz, H. (1972) Production, information costs, and economic organization. *American Economic Review* 62(5): 777–795.

Amin, A. and Cohendet, P. (2004) *Architectures of Knowledge: Firms, Capabilities, and Communities*. Oxford: Oxford University Press.

Ancori, B., Bureth, A. and Cohendet, P. (2000) The economics of knowledge: the debate about codification and tacit knowledge. *Industrial and Corporate Change* 9(2): 255–287.

Andersson, Å. and Beckmann, M. (2009) *Economics of Knowledge: Theory, Models and Measurements*. Cheltenham: Edward Elgar.

Anton, J. and Yao, D. (2005) Markets for partially contractible knowledge: bootstrapping versus bundling. *Journal of the European Economic Association* 3(2–3): 745–754.

Antonelli, C. (2003a) *The Economics of Innovation, New Technologies and Structural Change*. London: Routledge.

Antonelli, C. (2003b) Knowledge complementarity and fungeability: implications for regional strategy. *Regional Studies* 37(6–7): 595–606.

Arena, R., Festré, A., and Lazaric, N. (2012) Introduction. In R. Arena, A. Festré and N. Lazaric (eds.), *Handbook of Knowledge and Economics* (pp. 1–20). Cheltenham: Edward Elgar:.

Arrow, K. (1962a) The economic implications of learning by doing. *Review of Economic Studies* 29(3): 155–173.

Arrow, K. (1962b) Economic welfare and the allocation of resources to invention. In R.R. Nelson (ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors* (pp. 609–626). Princeton: Princeton University Press.

Arrow, K. (1994) Methodological individualism and social knowledge. *American Economic Review* 84(2): 1–9.

Arrow, K. (1996) The economics of information: an exposition. *Empirica* 23(2): 119–128.

Arrow, K. (2005) Correspondence, in 'symposium on information and knowledge in economics', *Econ Journal Watch* 2(1): 105.

Arrow, K. (2009) Some developments in economic theory since 1940: an eyewitness account. *Annual Review of Economics* 1, 1–16.

Aumann, R. (1976) Agreeing to disagree. *Annals of Statistics* 4(6): 1236–1239.

Battigalli, P. and Bonanno, G. (1999) Recent results on belief, knowledge and the epistemic foundations of game theory. *Research in Economics* 53(3): 149–225.

Beaudry, C. and Schiffauerova, A. (2009) Who's right, Marshall or Jacobs? The localization versus urbanization debate. *Research Policy* 38(2): 318–337.

Becker, G. and Murphy, K. (1992) The division of labor, coordination costs, and knowledge. *Quarterly Journal of Economics* 107(4): 1137–1160.

Bellante, D. and Garrison, R. (1988) Phillips curves and Hayekian triangles: two perspectives on monetary dynamics. *History of Political Economy* 20(2): 207–234.

Bicchieri, C. (1993) *Rationality and Coordination*. Cambridge University Press: Cambridge.

Binmore, K. (2005) Why the distinction between knowledge and belief might matter. *Econ Journal Watch* 2(1): 97–104.

Boettke, P. (1997) Where did economics go wrong? Modern economics as a flight from reality. *Critical Review* 11(1): 11–64.

Boettke, P. (2002) Information and knowledge: Austrian economics in search of its uniqueness. *Review of Austrian Economics* 15(4): 263–274.
Boland, L. (1992) *The Principles of Economics: Some Lies My Teacher Told Me*. London: Routledge.
Boldrin, M. and Levine, D. (2008) Perfectly competitive innovation. *Journal of Monetary Economics* 55(3): 435–453.
Boschma, R. (2005) proximity and innovation: a critical assessment. *Regional Studies* 39(1): 61–74.
Boulding, K. (1966) The economics of knowledge and the knowledge of economics. *American Economic Review* 56 (1/2): 1–13.
Braman, S. (2006) The micro- and macroeconomics of information. *Annual Review of Information Science and Technology* 40(1): 3–52.
Breschi, S. and Lissoni, F. (2001a) Knowledge spillovers and local innovation systems: a critical survey. *Industrial and Corporate Change* 10(4): 975–1005.
Breschi, S. and Lissoni, F. (2001b) Localised knowledge spillovers vs. innovative milieux: knowledge "tacitness" reconsidered. *Papers in Regional Science* 80(3): 255–273.
Bresnahan, T. and Trajtenberg, M. (1995) General purpose technologies 'Engines of growth'? *Journal of Econometrics* 65(1): 83–108.
Brökel, T. and Binder, M. (2007) The regional dimension of knowledge transfers—a behavioral approach. *Industry and Innovation* 14(2): 151–175.
Carlaw, K., Oxley, L., and Walker, P. (2006) Beyond the hype: intellectual property and the knowledge society/knowledge economy. *Journal of Economic Surveys* 20(4): 633–690.
Carrincazeaux, C., Lung, Y., and Vicente, J. (2008) The scientific trajectory of the French School of Proximity: interaction- and institution-based approaches to regional innovation systems. *European Planning Studies* 16(5): 617–628.
Chakraborty, A. and Harbaugh, R. (2010) Persuasion by cheap talk. *American Economic Review* 100(5): 2361–2382.
Cowan, R., David, P., and Foray, D. (2000) The explicit economics of knowledge codification and tacitness. *Industrial and Corporate Change* 9(2): 211–253.
Crawford, V. and Sobel, J. (1982) Strategic information transmission. *Econometrica* 50(6): 1431–1451.
Dancy, J. (1985) *An Introduction to Contemporary Epistemology*. Oxford: Basil Blackwell.
Dasgupta, P. (1980) Decentralization and rights. *Economica* 47(186): 107–123.
Dasgupta, P. and David, P. (1994) Toward a new economics of science. *Research Policy* 23(5): 487–521.
Dasgupta, P. and Stiglitz, J. (1980) Industrial structure and the nature of innovative activity. *Economic Journal* 90(358): 266–293.
David, P. and Foray, D. (2002) An introduction to the economy of the knowledge society. *International Social Science Journal* 54(171): 9–23.
Dekel, E. and Gul, F. (1997) Rationality and knowledge in game theory. In D.M. Kreps and K.F. Wallis (eds.), *Advances in Economics and Econometrics: Theory and Applications*, Seventh World Congress: Vol. I (pp. 87–172). Cambridge: Cambridge University Press.
Dekel, E., Lipman, B., and Rustichini, A. (1998) Standard state-space models preclude unawareness. *Econometrica* 66(1): 159–173.
Demsetz, H. (1969) Information and efficiency: another viewpoint. *Journal of Law and Economics* 12(1): 1–22.
Desrochers, P. (2001). Local diversity, technological creativity and technological innovation. *Growth and Change* 32(3): 369–394.
Desrochers, P. and Leppälä, S. (2011) Opening up the 'Jacobs Spillovers' black box: local diversity, creativity and the processes underlying new combi-nations. *Journal of Economic Geography* 11(5): 843–863.
Dolfsma, W. (2001) Metaphors of knowledge in economics. *Review of Social Economy* 59(1): 71–91.
Ellingsen, T. and Östling, R. (2010) When does communication improce coordination? *American Economic Review* 100(4): 1695–1724.
Farrell, J. and Rabin, M. (1996) Cheap talk. *Journal of Economic Perspectives* 10(3): 103–118.
Faulkner, P. and Runde, J. (2004) Information, knowledge and modelling economic agency. In J. B. Davis, A. Marciano and J. Runde (eds.), *The Elgar Companion to Economics and Philosophy* (pp. 423–445). Cheltenham: Edward Elgar.

Feldman, M. and Audretsch, D. (1999) Innovation in cities: science-based diversity, specialization and localized competition. *European Economic Review* 43(2): 409–429.
Ferreira, J. and Zamora-Bonilla, J. (2006) An economic model of scientific rules. *Economics and Philosophy* 22(2): 191–212.
Foley, R. (2002) Conceptual diversity in epistemology. In P.K. Moser (ed.), *The Oxford Handbook of Epistemology* (pp. 177–203). Oxford: Oxford University Press.
Foray, D. (2004) *The Economics of Knowledge. Rev. and enlargened translation of: L'économie de la connaissance (2000)*. Cambridge MA: The MIT Press.
Foss, K., Foss, N., and Klein, P. (2007) Original and derived judgment: an entrepreneurial theory of economic organization. *Organization Studies* 28(12): 1893–1912.
Foss, N. (1999) The use of knowledge in firms. *Journal of Institutional and Theoretical Economics* 155(3): 458–486.
Gertler, M. (2003) Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there). *Journal of Economic Geography* 3(1): 75–99.
Gettier, E. (1963) Is Justified true belief knowledge? *Analysis* 23(6): 121–123.
Glaeser, E., Kallal, H., Scheinkman, J., and Shleifer, A. (1992) Growth in cities. *Journal of Political Economy* 100(6): 1126–1152.
Goldman, A. (1999) *Knowledge in a Social World*. Oxford: Clarendon Press:.
Grossman, S. and Stiglitz, J. (1980) On the impossibility of informationally efficient markets. *American Economic Review* 70(3): 393–408.
Hands, D. (2001) *Reflection without Rules: Economic Methodology and Contemporary Science Theory*. Cambridge: Cambridge University Press.
Hansen, N. (2002) Dynamic externalities and spatial innovation diffusion: implications for peripheral regions. *International Journal of Technology, Policy and Management* 2(3): 260–271.
Hardin, R. (2009) *How Do You Know? The Economics of Ordinary Knowledge*. Princeton: Princeton University Press.
Hayek, F. (1937) economics and knowledge. *Economica*, New Series 4(13): 33–54.
Hayek, F. (1945) The use of knowledge in society. *American Economic Review* 35(4): 519–530.
Heath, W. (2007) Hayek revisited: planning, diversity, and the vox populi. *The Independent Review* 12(1): 47–70.
Hellwig, C. and Veldkamp, L. (2009) Knowing what others know: coordination moves in information acquisition. *Review of Economic Studies* 76(1): 223–251.
Hellwig, M. and Irmen, A. (2001) Endogenous technical change in a competitive economy. *Journal of Economic Theory* 101(1): 1–39.
Hild, M., Jeffrey, R. and Risse, M. (1999) Aumann's "no agreement" theorem generalized. In C. Bicchieri, R. Jeffrey and B. Skyrms (eds.), *The Logic of Strategy* (pp. 92–100). Oxford: Oxford University Press.
Hintikka, J. (1962) *Knowledge and Belief: An Introduction to the Logic of the Two Notions*. Ithaca, NY: Cornell University Press.
Hirshleifer, J. (1973) Where are we in the theory of information? *American Economic Review* 63(2): 31–39.
Holmström, B. and Roberts, J. (1998) The boundaries of the firm revisited. *Journal of Economic Perspectives* 12(4): 73–94.
Hong, L. and Page, S. (2001). Problem solving by heterogeneous agents. *Journal of Economic Theory* 97(1): 123–163.
Hopenhayn, H., Llobet, G., and Mitchell, M. (2006) Rewarding sequential innovators: prizes, patents, and Buyouts. *Journal of Political Economy* 114(6): 1041–1068.
Keller, W. (2002) Geographic localization of international technology diffusion. *American Economic Review* 92(1): 120–142.
Kling, A. (2010) *Unchecked and Unbalanced: How the Discrepancy Between Knowledge and Power Caused the Financial Crisis and Threatens Democracy*. Lanham: Rowman & Littlefield Publishers.
Knight, F. (1921) *Risk, Uncertainty and Profit*. Washington, D. C.: Beard Books.
Koppl, R. (2006) Epistemic systems. *Episteme* 2(2): 91–106.
Krishna, V. and Morgan, J. (2001) A model of expertise. *Quarterly Journal of Economics* 116(2): 747–775.

Lamberton, D. (1971) Introduction. In D.M. Lamberton (ed.), *Economics of Information and Knowledge* (pp. 7–17). Harmondsworth: Penguin Books.
Latsis, S. (1972) Situational determinism in economics. *British Journal for the Philosophy of Science* 23 (3): 207–234.
Lavoie, D. (1985) *Rivalry and Central Planning: The Socialist Calculation Debate Reconsidered*. Cambridge: Cambridge University Press.
Lenzen, W. (1978) Recent Work in Epistemic Logic. *Acta Philosophica Fennica* 30 (1): 1–219.
Leppälä, S. (2010) Hayek on Prices and Knowledge: Supplementing "The Use of Knowledge in Society" with The Sensory Order. In W. N. Butos (ed.), *The Social Science of Hayek's 'The Sensory Order'*, Advances in Austrian Economics, Vol. 13 (pp. 237–259). Bingley: Emerald Group Publishing Limited.
Leppälä, S. (2011) *Essays in the Economics of Knowledge*. Publications of the Turku School of Economics A-8: 2011. Doctoral thesis at the Department of Economics, University of Turku. Available at: http://info.tse.fi/julkaisut/vk/Ae8_2011.pdf. Accessed December 25, 2013.
Leppälä, S. (2012) An Epistemological perspective on knowledge transfers: from tacitness to capability and reliability. *Industry and Innovation* 19(8): 631–647.
Leppälä, S. and Desrochers, P. (2010) The division of labor need not imply regional specialization. *Journal of Economic Behavior and Organization* 74 (1–2): 137–147.
Li, J. (2009) Information structures with unawareness. *Journal of Economic Theory* 144(3): 977–993.
Lo, A. (2008) Efficient markets hypothesis. In S.N. Durlauf and L. E. Blume (eds.), *The New Palgrave Dictionary of Economics*, Palgrave Macmillan, 2008, The New Palgrave Dictionary of Economics Online, Palgrave Macmillan. 16 August 2011, DOI:10.1057/9780230226203.0454
Loasby, B. (1986) Organisation, competition, and the growth of knowledge. In R.N. Langlois (ed.), *Economics as a process: Essays in the New Institutional Economics* (pp. 41–57). Cambridge University Press: Cambridge.
Loury, G. (1979) Market structure and innovation. *Quarterly Journal of Economics* 93(3): 395–410.
Lucas, R. (1988) On the mechanics of economic development. *Journal of Monetary Economics* 22(1): 3–42.
Lundvall, B. (2004) The Economics of Knowledge and Learning. In J. Christensen and B. Lundvall (eds.), *Product Innovation, Interactive Learning and Economic Performance (Research on Technological Innovation, Management and Policy)*, Vol. 8 (pp. 21–42). Amsterdam: Elsevier.
Machlup, F. (1962) *The Production and Distribution of Knowledge in the United States*. Princeton: Princeton University Press.
Machlup, F. (1980) *Knowledge: Its Creation, Distribution, and Economic Significance, Volume I: Knowledge and Knowledge Production*. Princeton: Princeton University Press.
Machlup, F. and Penrose, E. (1950) The patent controversy in the nineteenth century. *Journal of Economic History* 10(1): 1–29.
Manski, C. (2004) Social learning from private experiences: the dynamics of the selection problem. *Review of Economic Studies* 71(2): 443–458.
Marschak, J. (1960) Remarks on the Economics of Information. In *Contributions to Scientific Research in Management* (pp. 79–98). Berkeley: University of California Printing Department.
Marshall, A. (1890) *Principles of Economics*, 8th edn. London: MacMillan.
Metcalfe, J. and Ramlogan, R. (2005) Limits to the economy of knowledge and knowledge of the economy. *Futures* 37(7): 655–674.
Mirowski, P. (2009) Why There Is (As Yet) No Such Thing as an Economics of Knowledge. In H. Kincaid and D. Ross (eds.), *The Oxford Handbook of Philosophy of Economics* (pp. 99–156). Oxford: Oxford University Press.
Mokyr, J. (2002) *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton: Princeton University Press.
Musgrave, R. and Musgrave, P. (1973) *Public Finance in Theory and Practice*. 2nd edn. Tokyo: McGraw-Hill.
Mäki, U. (2005) Economic epistemology: hopes and horrors. *Episteme* 1(3): 211–220.
Møen, J. (2005) Is Mobility of technical personnel a source of R&D spillovers? *Journal of Labor Economics* 23(1): 81–114.
Nelson, R. (1959) The Simple economics of basic scientific research. *Journal of Political Economy* 67(3): 297–306.

Nelson, R. and Winter, S. (1982) *An Evolutionary Theory of Economic Change*. Cambridge: Belknap Press.
Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company*. New York: Oxford University Press.
Nooteboom, B. (2000) *Learning and Innovation in Organizations and Economies*. Oxford: Oxford University Press.
North, D. (1990) *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.
North, D. (2005) *Understanding the Process of Economic Change*. Princeton: Princeton University Press.
O'Driscoll, G. and Rizzo, M. (1985) *The Economics of Time and Ignorance*. Oxford: Basil Blackwell Ltd.
Page, S. (2007) *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*. Princeton: Princeton University Press.
Penrose, E. (1959) *The Theory of the Growth of the Firm*. Oxford: Basil Blackwell.
Perraton, J. and Tarrant, I. (2007) What does tacit knowledge actually explain? *Journal of Economic Methodology* 14(3): 353–370.
Pigou, A. (1920) *The Economics of Welfare*, 4th edn. London: MacMillan.
Plant, A. (1934) The economic theory concerning patents for inventions. *Economica* 1(1): 30–51.
Polanyi, M. (1958) *Personal Knowledge: Towards a Post-Critical Philosophy*. London: Routledge.
Rabin, M. (1993) Information and the control of productive assets. *Journal of Law, Economics, & Organization* 9(1): 51–76.
Rae, J. (1834) *Statement of Some New Principles on the Subject of Political Economy: Exposing the Fallacies of the System of Free Trade, and of Some Other Doctrines Maintained in the "Wealth of Nations"*. Boston: Hilliard, Gray and Co.
Richardson, G. (1960) *Information and Investment: A Study in the Working of the Competitive Economy*. London: Oxford University Press
Romer, P. (1990) Endogenous technological change. *Journal of Political Economy* 98(5): S71–S102.
Rosenberg, N. and Birdzell, L. (1986) *How the West Grew Rich: The Economic Transformation of the Industrial World*. New York: Basic Books.
Samuelson, L. (2004) Modelling knowledge in economic analysis. *Journal of Economic Literature* 42(2): 367–403.
Schumpeter, J. (1942) *Capitalism, Socialism and Democracy*, 3rd edn. New York: Harper Perennial.
Sena, V. (2004) The return of the Prince of Denmark: a survey on recent developments in the economics of innovation. *Economic Journal* 114(496): F312–F332.
Shackle, G. (1972) *Epistemics & Economics: A Critique of Economic Doctrines*. London: Cambridge University Press.
Scotchmer, S. (1991) Standing on the shoulders of giants: cumulative research and the patent law. *Journal of Economic Perspectives* 5(1): 29–41.
Simon, H. (1955) A Behavioral model of rational choice. *Quarterly Journal of Economics* 69(1): 99–118.
Smith, A. (1776) *An Inquiry into the Nature and Causes of the Wealth of Nations*. New York: Modern Library.
Solow, R. (1956) A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70(1): 65–94.
Spence, M. (1973) Job Market signalling. *Quarterly Journal of Economics* 87(3): 355–374.
Stalnaker, R. (1999) Knowledge, belief, and counterfactual reasoning in games. In C. Bicchieri, R. Jeffrey, and B. Skyrms, (eds.), *The Logic of Strategy* (pp. 3–38). Oxford: Oxford University Press.
Stigler, G. (1961) The economics of information. *Journal of Political Economy* 69(3): 213–225.
Stiglitz, J. (1975) The theory of "screening," education, and the distribution of income. *American Economic Review* 65(3): 283–300.
Stiglitz, J. (1985) Information and economic analysis: A perspective. *Economic Journal* 95, Supplement: Conference Papers, 21–41.
Stiglitz, J. (2000) The Contributions of the economics of information to twentieth century economics. *Quarterly Journal of Economics* 115(4): 1441–1478.
Stiglitz, J. (2002) Information and the change in the paradigm in economics. *American Economic Review* 92(3): 460–501.
Sunstein, C. (2006a) Deliberating groups versus prediction markets (or Hayek's challenge to Habermas). *Episteme* 3(3): 192–213.

Sunstein, C. (2006b) *Infotopia: How Many Minds Produce Knowledge*. Oxford: Oxford University Press.
Tullock, G. (1966) *The Organization of Inquiry*. Durham: Duke University Press.
Usher, D. (1964) The Welfare economics of invention. *Economica* 31(123): 279–287.
Walker, P. (2010) The (non)theory of the knowledge firm. *Scottish Journal of Political Economy* 57(1): 1–32.
Warsh, D. (2007) *Knowledge and the Wealth of Nations: A Story of Economic Discovery*. New York: W.W. Norton.
Weitzman, M. (1998) Recombinant growth. *Quarterly Journal of Economics* 113(2): 331–360.
Wolfers, J. and Zitzewitz, E. (2004) Prediction markets. *Journal of Economic Perspectives* 18(2): 107–126.
Wright, B. (1983) The economics of invention incentives: patents, prizes, and research contracts. *American Economic Review* 73(4): 691–707.
Zappia, C. (1996) The notion of private information in a modern perspective: a reappraisal of Hayek's contribution. *European Journal of the History of Economic Thought* 3(1): 107–131.