

Leppälä, Samuli

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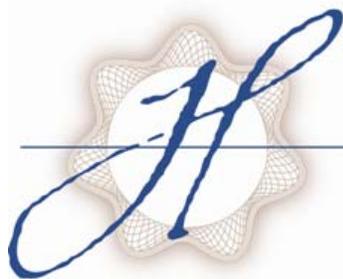
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ECONOMIC ANALYSIS OF KNOWLEDGE: THE HISTORY
OF THOUGHT AND THE CENTRAL THEMES

BY SAMULI LEPPÄLÄ

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

Samuli Leppälä

Postdoctoral Researcher

Department of Economics, University of Turku

Email: samuli.leppala@utu.fi

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 the 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. Nevertheless, one can identify a continuing tradition which analyses various aspects of the generation, dissemination and use of knowledge in the economy.

JEL Classifications: D80, O30, I20, B00.

Keywords: knowledge, information, belief, uncertainty, innovation, intellectual property rights, scientific research, technological change.

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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 Kenneth Boulding (1966, 1), who was apparently the first to use the name of this sub-discipline 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 & Beckmann 2009) and it also reappeared in academic journal articles (e.g. Ancori et al. 2000; Antonelli 2003b; Lundvall 2004). Closely related to the discipline, while from different perspectives, were the recent books by Warsh (2007) and Hardin (2009).

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 again later. A reason, perhaps, is that these are perceived in economics as such grand questions and themes with no clear or established way to approach them. By now, however, Foray (2004) argues that the economics of knowledge has been finally established as an original discipline. Let us next concentrate, then, on what he and others see as the defining characteristics of the discipline.

Foray writes 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, for example, had received the attention of several early economists, by the late 20th century these issues had become increasingly important. Foray and others (e.g. Antonelli 2003b; Lamberton 1971; Lundvall 2004; Machlup 1980; Stiglitz 2000) use interchangeable concepts to describe the central themes in the economics of knowledge, but three themes emerge among them: the generation, dissemination, and use of knowledge. Our later discussion will revolve around this taxonomy.

Foray makes the case that the economics of knowledge deserves to be identified as an original discipline, distinct from others such as the economics of research, the economics of innovation, or the economics of information. This is because it does not exclusively confine itself to the study of formal production of technological knowledge (i.e. the economics of research, or invention) or its underlying conditions and consequences (i.e. the economics of innovation). Nor does it exclusively study decision-making under imperfect or asymmetric information, which is the domain of the economics of information. In its broadest sense, the economics of knowledge includes all these and more. 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) diagonally opposite thesis that "there is (as yet) no such thing as an economics of knowledge." To answer that question we perhaps should first look at the set of themes that this broad view encompasses.

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. Foray sees Adam Smith, Karl Marx and Joseph Schumpeter as the historical figures behind the discipline, whereas the unquestionable latter-day pioneers are, in addition to Hayek and Machlup, Herbert Simon and Kenneth Arrow. As the works of these authors suggest, the early foundations of the discipline are in diverse paths of research. 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. Now, it is unclear whether the economics of information should be included, as it is well-recognized discipline on its own. To be sure, however, the topics of the narrow view and those of economics of information are largely intertwined and in the past not much distinction was drawn between the two areas. An example is the book edited by D. M. Lambertson (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.

Foray notes that Machlup's work, in particular, covers a vast domain, from knowledge creation and transfer to knowledge sectors and industries, to the theory of choice and expectations under uncertainty and incomplete information. 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's (1966) view of the scope of the economics of knowledge is similarly broad. He remarks that three areas of economic thought where knowledge has been neglected and where there is henceforth demand for such a work are the theory of the market, the theory of development, and the theory of decision making (both public and private). As such, we proceed forward with this broader view of the economics of knowledge while keeping the discussed reservations of its scope in mind.

While most aspects of the generation, dissemination and use 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 the one hand, the microeconomics of knowledge can provide part of an explanation for the economic fluctuations that we observe in the macro economy. On the other hand, creation and diffusion of new technologies, in particular, result in economic growth, a view which is the fundamental building block of the endogenous growth theory (e.g. Romer 1990). Hence, while the discussion in this survey mostly concerns the microeconomics of knowledge in its various forms, it is good to keep in mind that these are not interesting and relevant questions for their own sake only, but ultimately have implications for macroeconomic issues as well (see, David & 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. Unlike labor economics, for example, it does not solely study any particular market. 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). Therefore, the economics of knowledge offers a perspective that can, and has been, applied to labor economics, finance and many other fields. However, the economics of knowledge is neither a tool nor a method like game theory, for example. In fact, game theory has proven useful in many questions that the economics of knowledge is concerned with. Perhaps the best way to describe the economics of

knowledge is, then, an “approach”. It is an approach that analyses any given economic phenomenon from the point of view of knowledge. Behavioral economics is perhaps similar, since it comes with insights and approaches that can be applied to many different economic phenomena.

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 paper. 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 by studying knowledge we are interested in the contents of the human mind regarding the facts about the world outside. This approach lets us define our scope further: we leave aside skills or know-how, to the extent they are not about beliefs of the world outside, and information embedded goods, such as computer software, since that does not refer to the contents of the mind per se. We use information, for now, as shorthand for communicated knowledge.

Defining economics is equally difficult and various definitions have been offered, and later contested, throughout the history of economic thought; some sticking longer than the others. But for all its apparent crudeness, let us confine to 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. The histories of these two types in economics are somewhat different, even if overlapping. This division was proposed by Richardson (1960), even though he used the concept of information instead of knowledge. Technical knowledge refers to production possibilities regarding the development of new products or services or more efficient production of the existing ones. Usually, technology in economic analysis simply means the “unexplained constraint on human action in relation to production” (Metcalf 2010, 155). Scientific knowledge, and its generation, dissemination and use, is a part of the same phenomenon, as its significance is usually seen, at least in economic literature, as the progenitor of technical knowledge. Most of the studies of the kind have been dubbed under the

headings of the economics of invention and the economics of innovation. The first is usually confined to knowledge production, whereas the latter studies the issue more broadly, including the dissemination of new technologies and the economic impact of technological change.

Market knowledge is different in a sense that it concerns not only the available production technologies, but the decision-making environment in general. It includes knowledge about the available resources and the market in general, such as consumers' preferences, rival products and the actions and beliefs of your competitors, from the point of view of a seller, and product quality and other issues, from the point of view of a consumer. Lachmann (1976, 55) concisely specifies market knowledge as the knowledge of tastes and resources.

These two types of knowledge are invoked in explaining different types of phenomena. Technical knowledge concerns technological development and subsequent economic growth. Market knowledge concerns decision-making and subsequent market coordination (or discoordination). Many of these latter issues are categorized as the economics of information. Therefore, while much research is confined to specific topics, it is good to keep in mind that there is a wider perspective of economic analysis of knowledge in the background.

2 ON THE HISTORY OF ECONOMIC ANALYSIS OF KNOWLEDGE

To write a complete bibliography of the economics of knowledge is next to impossible, since perhaps the majority of prolific economists have written something on the topic. At the best, then, what can be offered here is a brief review of central ideas and approaches, and the authors behind them that stand out in the literature. We will first follow the developments in the economics of technical knowledge and after that in the economics of market knowledge, as these studies have, to some extent, followed their own 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 technical 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 even more efficient. Later in the 20th century, one can see a connection here to Kenneth Arrow's (1962a) idea of "learning-by-doing", i.e. how people accumulate (technical) knowledge as a by-product of their work and specialization.

However, it took a while before technical 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, which seemed inevitable for many economists (Warsh 2007). The Marginal Revolution was, of course, a major event in the history of economic thought, but Menger, Walras and Jevons had been more interested in the demand side of the economy and the

connection between value and utility. The next to touch upon the topic of technical knowledge, and from a new perspective, was Alfred Marshall (1842–1924).

In his seminal work, *The Principles of Economics*, Marshall (1890) addressed the issue of why some industries co-locate in particular places (see, also, Ellison et al. 2010). Besides the advantages provided by the physical or economic conditions of a place, Marshall noted that new inventions tended to spread more easily in these locations. 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. What became important for Marshall was the dissemination of technical 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” (ibid. IV.X.7).

A.C. Pigou (1920) took Marshall’s idea of external economies further by developing the concepts of negative and positive externalities. Both were deemed as sources of market failure: when marginal private costs are less than marginal social cost, there is overproduction from the social point of view (negative externalities) and when marginal private benefits are less than marginal social benefits, there is underproduction (positive externalities). Negative externalities are uncompensated nuisances or damages to others and their property. Positive externalities were, accordingly, uncompensated benefits, the most important example of which was according to Pigou (1920, II.IX.11) scientific research. For the first time the generation of scientific and technical knowledge was argued to possess a problem for the market economy, even though in essence the similar argument had been put forward by John Rae (1834) among others, who had 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, though research activities as such were not always in the epicenter of these discussions (see, for example, Demsetz 1969).

Meanwhile, another idea regarding technological change was put forward by Joseph Schumpeter. Schumpeter (1942) argued that the capitalist economy was repeatedly transformed by a process called creative destruction. The engine of the process was entrepreneurs who constantly developed new innovations. Interestingly, Schumpeter makes a link from technical 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 disequilibrating force. Initially, Schumpeter's argument seems not to have gained much attention, but later scholars of entrepreneurship and innovation placed him high in their ranking. A reason, perhaps, is that while Schumpeter did not offer a detailed account of technological change, he presented it as endogenous to the economy, hence something that economists can explain rather than take as given and beyond the scope of their study.

As mentioned earlier, the most prolific economist studying technical knowledge and the economics of knowledge in general was Fritz Machlup. His 1962 book, *The Production and Distribution of Knowledge in the United States*, 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. Later Machlup 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. These three addressed topics such as creation, diffusion, and utilization of knowledge (1980), branches of learning (1982), and the economics of information and human capital (1984). 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 in the case of research activities, several papers using the Pigouvian framework appeared roughly at the same time. These include Nelson (1959), Arrow (1962b), Usher (1964) and Shell (1966). Among these, particularly Nelson (1959) and Arrow (1962) were successful in establishing the view that the free market was unable to provide sufficient incentives to generate an efficient level of research investments. Two of the most important solutions to the underprovision problem were seen in the patent system (Usher 1964) and government funding of research (Arrow 1962).

The costs and benefits of the patent system had been under discussion since the beginning (Machlup & Penrose 1950), but it is fair to say for a long time the theories of inventive activities (e.g. Wyatt 1986) automatically assumed the presence of intellectual property rights. Only more recently have studies on invention in a competitive economy appeared (e.g. Hellwig and Irmen 2001; Boldrin &

Levine 2002; Boldrin & 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 positive externalities of technical knowledge were due to its inappropriability: the inventor was unable to capture all the benefits of his invention. Later, in the public goods literature (Musgrave & 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. Richard and Peggy Musgrave (1973) also identified another characteristic of public goods, nonrivalness. This was particularly important in case of knowledge, since it is not rival in use and the same knowledge can be used both by infinite number of people and infinitely.

The (partial) public good nature of technical knowledge is also an important characteristic behind the two most recent theories of growth. Technical and scientific knowledge was the engine of growth behind the neoclassical growth theory (Solow 1956), though 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, which resulted in economy-wide growth due to the externalities. In Warsh's (2006) 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. Later literature dubbed this discovery as "Arrow's information paradox", which provided another rationale for the need for intellectual property rights in markets for information.

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 antitrust issues in research activities (e.g. Scotchmer 1991; Hopenhayn et al. 2006). The idea of cumulative research or sequential innovation, an issue which, as we have seen, was 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 & Stiglitz 1980; Hörner 2004; Aghion et al. 2005).

Much of the work done by economic geographers, economists and other innovation scholars have been undertaken in the field of economics of innovation, broadly conceived (e.g. Klette & Kortum 2004; Jones 2009; Young 2009). Antonelli (2003a) is a good overview of the themes studied in the field. A central feature in the field today, and a result of past scholarly work, seems to be the studied two-way causation between technology and industry. The generation of technical knowledge and its effects were no longer studied in isolation and hence the legacy of Schumpeter was reanimated (see, also, 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 pointed out 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 the "creative destruction".

To this long list another line of research, not concerned as much with technical but scientific knowledge, needs to be added. The new economics of science (Dasgupta & 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 also labeled as the economics of scientific knowledge (Hands 2001; Ferreira & 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 pointed out that the argument fails because scientists are motivated by many other things besides veracity. However, private vices can also yield public virtue, as is many times the case in economic phenomena. 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 study 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 & Morgan 2001; Li & Suen 2004; Li 2010). 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 technical knowledge and market knowledge, the latter of which will be 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. For Schumpeter, 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.

Secondly and related to the first point, the knowledge of new technologies is not automatically disseminated and implemented. New technical knowledge is not sufficient for economic growth. This point is well made by Nathan Rosenberg and Luther Earle Birdzell (1986), who in their book, *How the West Grew Rich: The Economic Transformation of the Industrial World*, illustrate how many important technologies were originally developed outside the Western world, but in there they finally flourished and brought prosperity. Once again, institutions do 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 2006, 315).

2.2 Decision-making, uncertainty and market coordination

The following will offer a brief overview of the history of thought regarding market knowledge. Knowledge of market conditions in general 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 making decision at the individual or a more aggregate level of several individuals working together. Most of the studies concerned with these issues have adopted the term of the economics of information (or information economics), though there are some who have deliberately avoided that. As can be expected, however, these issues have 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 "no", because the required knowledge was dispersed in the economy, held by each individual and thus not possible to collect. Hayek (1937) had earlier put forward this dispersed knowledge view, arguing that

Smith's division of labor automatically implied a division of knowledge: each individual knew different things, more about the particular circumstances of their time and place. In this paper, Hayek noted also 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." Coming back to the calculation debate, however, Hayek argued that the free market, unlike socialism, was able to efficiently use the dispersed knowledge through the price system.

Hayek's contribution in the 1945 article was to study the use of knowledge given its dispersed nature and, to a lesser extent, how that knowledge was disseminated through the price system (in some sense 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 (technical) knowledge production (Hirshleifer 1973; Dasgupta 1980). It is debatable whether Hayek won the argument concerning the feasibility socialism in that day, 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 concepts of 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 marginal benefit of the search would be equal. Any lack of information could then be contributed to the search costs, and hence any ignorance would be rational. Predating the later theoretical developments, Demsetz and Alchian (Demsetz 1969; Alchian & Demsetz 1972) would argue that the consequences of asymmetric information, as they were later termed, did not imply market failure but were rational responses to specific information costs.

The particular type of information, which Stigler (1961) studied in his paper, was information on prices. If all sellers did not charge the same price for their product, or at least the buyer did not know if

that was the case, the buyer would visit different sellers until he would find a price that satisfied his optimization problem. Contra to Hayek (1945), in Stigler's model the individuals did not know the market price(s) automatically, and therefore the informational role of prices was quite different. The informational role of prices was also later addressed by Grossman and Stiglitz (e.g. 1980). They found Hayek's reasoning 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 contributing factor for these opposing conclusions can be found in conceptual differences regarding knowledge and information (Zappia 1996).

Much of the economics of information which was done in the 20th century was concerned with imperfect knowledge, and when knowledge was imperfect choices would involve uncertainty. Many of these studies, however, would concern choices under risk, rather than uncertainty, to use the famous dichotomy of Frank 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 (true) 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 would become G.L.S. Shackle's (e.g. 1972) task to try to convince the profession that "uncertainty" in making rational choices should be taken more seriously in economic analysis. The meaning of a "choice" would be severely impaired when it was reduced to a technical calculation problem. As said by Arrow (1962b) already, uncertainty is, of course, prevalent in decisions concerning R&D investments.

Information economics largely developed in its own path (Stiglitz 1985 and 2002, Braman 2006, and Arrow 2009 offer a perspective on these developments). The final breakthrough of the field was due to the analysis of asymmetric information. Asymmetric information considered contracts between two parties, where one knew more about the object of the contract than the other. The key contributions, the authors of which shared the Nobel Prize in Economics in 2001, were Akerlof (1970), Spence (1973) and Stiglitz (1975). 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 rely on the fact that communication is costly, which guarantees that any sent message is a true statement of a fact. Most of human communication, however, is not like that, but for a long time economists considered that as only "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 one and nothing could be done to see 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, which studies the situations where the argument of uninformative communication holds or not, has emerged (e.g. Crawford & Sobel 1982; Farrell & Rabin 1996; Levy & Razin 2007; Chen et al. 2008; Mullainathan et al. 2008; Chakraborty & Harbaugh 2010). The central result that was found was 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 regular,

costless communication depends likewise on incentives. In some cases, such communication can improve the coordination of actions (Ellingsen & 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 (e.g. 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. Bounded rationality and behavioral economics in general, however, while also concerned with knowledge and learning, put perhaps more emphasis on the cognitive limitations of using the available information efficiently than the lack or imperfection of knowledge itself. To add to the ever-growing list of subfields, bounded rationality, when coupled with the study of institutions, has also led to a new field, the economics of the mind, which borrows ideas from cognitive science and theoretical psychology (Rizzello 1999), further obscuring disciplinary boundaries.

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 & 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. This issue would seem especially acute in universities, and thus worth exploring by the economics of scientific knowledge.

So far we have discussed the economists’ rationality assumption in passing, but not extensively its connection with assumptions about 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, 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. This development is due to a large extent 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 theoretical models it is very relevant what is assumed about what the decision-makers know about their environment and each other (Bicchieri et al. 1999). 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, i.e. knowing about knowledge that you yourself and others have (e.g. Hellwig & 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). Of much interest is also the study and many applications of prediction markets through which dispersed knowledge is used in a 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 idea of the wisdom of crowds, i.e., how a group of individuals are able to make better decisions collectively than even the brightest individuals in that group could alone, is very interesting from the point of view of the organization of economic activity in a society. 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 (see, also, Leppälä 2011c).

Stiglitz (2000), while known to be in disagreement on many other issues, gives Hayek full credit for pointing out how important the questions on knowledge are for the economic profession. Stiglitz (1985) makes the same point made by others before him that informational considerations are a foundational part of economic analysis and notes that these considerations have had both a negative and a 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, 1469 & 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. Should we then simply use the economics of information as the principal category of the discipline? While nothing, of course, prevents it, in my opinion “knowledge” is a more natural choice. While (the exchange of) information is an integral part of economic analysis of knowledge, without the concept of knowledge, the analysis of information misses some key aspects that should be considered. This issue and the connection between information and knowledge will be discussed in the next section.

3 SOME CENTRAL ISSUES IN THE ECONOMICS OF KNOWLEDGE

3.1 The characteristics of knowledge as an economic good

Machlup (1962) was the first to explicitly study knowledge as an economic good. According to him, knowledge can appear as one of the three different types of a good: 1) an investment good, (e.g. formal education or scientific research); 2) an intermediate good, (e.g. market research or financial analysis); and 3) a consumption good, (e.g. art or general literature). Furthermore, since Pigou (1920) particularly scientific and technical knowledge has been regarded, more or less, as a public good and a source of positive externalities.

While concepts to describe the exceptional characteristics of knowledge vary in the literature, the ones used to make the distinction between private and public goods, rivalry and excludability, describe them best. Nonrivalry of knowledge implies that its use is unlimited in principle (both in time and between users) and nonexcludability that its use is or cannot be limited in practice. The standard argument in the literature is that without excludability there is no private gain to invest in knowledge and therefore it must be artificially created with intellectual property rights or the investments need to be funded through taxes (e.g. Arrow 1962b and 1996). Some argue that the underproduction issue is less severe in reality, since knowledge has some partial excludability, not only due to intellectual property rights but also because of the trade secrets and tacitness of knowledge. However, they do agree that excludability is desirable in principle.

Leppälä (2011b) analyzes this issue with a game-theoretic discrete public good model. Nonrivalry implies that knowledge goods are lumpy or indivisible, which suggests that they should be studied as discrete public goods. In addition, since there is a possibility for collective gain, there is also a possibility for collective, cooperative action for which a game-theoretic approach is well-suited. The

results demonstrate that both pure excludability and pure nonexcludability are equally inefficient, as they create either too much or too little investment effort. The optimal level of excludability lies in between the extremes as a function of the costs and benefits of the knowledge investment. This result clarifies the controversy regarding the desirability of intellectual property rights. If the optimal level of excludability is different to different industries and types of knowledge, however, this suggests major challenges for the intellectual property law. One study cannot, of course, be conclusive, but it introduces a new and promising perspective to study the production of scientific and technical knowledge, R&D cooperation and the impact of intellectual property rights.

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 & Audretsch 1996). The motivation for that 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 it is increasingly so because knowledge spillovers are locally bounded, which provides a reason to locate near its sources (e.g. Gertler 2003; Keller 2002).

Knowledge spillovers are local public goods generating positive externalities. However, in what sense are these knowledge externalities a symptom of a market failure, caused by nonexcludability, or are they the engine of growth and development? This issue goes into the heart of the endogenous growth theory (Romer 1990). Furthermore, it is not even perfectly clear that knowledge spillovers, as they are studied in the contemporary literature, are truly knowledge externalities (Breschi & Lissoni 2001a). When one studies the effect of cooperation and social networks behind innovative activities, knowledge spillovers are definitely deliberate. Patent data is also constantly used in these studies, which seems to counter the idea of externality, since patents are, at least in theory, developed to internalize social benefits. In addition, one channel of knowledge spillovers is argued to be labor mobility between firms (e.g. Audretsch & Keilback 2005). However, 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 & 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 & 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.

A step in this direction is taken in Desrochers and Leppälä (2011). In this study, we concentrate on Jacobs spillovers, which have received less attention. How new technologies are disseminated within an industry (MAR or Porter spillovers) as well as adopted in a wide set of industries (general purpose technologies) are better documented. At the heart of Jacobs spillovers, however, is not only the dissemination of technical knowledge, but that it ultimately creates new innovation when, paraphrasing Jacobs (1969), old work is connected with new work. We conducted a qualitative survey of individual inventors and identified three broad, although not mutually exclusive, sets of circumstances through which individuals found new uses or applications for existing products and created new combinations of existing products, processes and materials: 1) by adding to, switching or adapting specific know-how to other lines of work; 2) by observing something in another line of work and incorporating it into one’s own line of work; and 3) through formal and informal multidisciplinary teams working towards the creation of new products and processes (Desrochers & Leppälä 2011).

3.3 Knowledge as an input and output of creative activities

As already noted by Machlup (1962), knowledge is both the input and output of an R&D investment. Among others, the sequential innovation literature takes the use of past knowledge for the generation new as a requirement for research activity. More generally, the different phases of both market and technical knowledge processes are highly interdependent. Thus while sometimes it is necessary to focus on the generation, diffusion or use of knowledge, the linkages between them should be kept in mind.

When making a research investment, the dissemination as well as the later use of this technical knowledge is important. In addition, as noted earlier, a research investment is itself a decision, and hence a use of knowledge, under uncertainty. As is the central idea behind Jacobs spillovers (Desrochers & Leppälä 2011), generated technical knowledge is not only disseminated, but the dissemination itself can cause the creation of new knowledge. All the phases are also connected to and dependent on the available market knowledge. Interestingly enough, Jacobs spillovers were also seen as the driving force behind the endogenous growth theory (Lucas 1988).

Furthermore, economic development and the coordination of economic activities depend both on the use of existing knowledge and the growth of knowledge. This perspective effectively links together superficially distinct issues regarding market knowledge, on the one hand, and technical knowledge, on the other. Efficient generation and dissemination of technical knowledge depend on market knowledge and efficient use of market knowledge depends on the existing technical knowledge.

The notion of creativity, whether we talk about the inventive action, the economic application of an invention or the entrepreneurial imagination to discover 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 was recently discovered by economists Hong and Page (2001) and Page (2007), who also demonstrated how it operates or fails to operate in different situations. This phenomenon is foundational to the wisdom of crowds and the whole Hayekian view of the use of knowledge in society.

Nevertheless, it is perhaps foremost the study of incentives (to generate, disseminate and use knowledge) where economists have a comparative advantage and can show how these matter for the economies of knowledge. To be more precise, it is the study of incentives that individuals have; the notion of which refers to methodological individualism, one of the well-recognized building blocks of economic analysis (for references, see Leppälä & Desrochers 2010). While we are not only interested in individuals in isolation but as members of groups and societies, group and societies as such do not know or act based on their knowledge. There is no direct access, i.e. telepathy, to each other's minds, and hence knowledge can only be shared indirectly. According to Arrow (1994), knowledge has an irremovable social component but can only be absorbed individually. 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). For example, in the case of public good knowledge, a particular piece of knowledge may in principle satisfy the criteria of public goods but whether or not it becomes, 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 later discussions about the informational role of the price system. The impossibility of informationally efficient markets (Grossman & Stiglitz 1980), which was presented above, is ultimately framed as a public good problem: Why would individuals make costly investments to acquire information if others are able to free-ride on their benefit? However, as argued in Leppälä (2010), 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. 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 facing the changing prices. As such, there is a large contrast to the view presented by Grossman and Stiglitz (1980).

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; Blume & Easley 2006), could provide a basis for the efficient market hypothesis as a learning process.

3.4 Tacit knowledge

Tacit knowledge is a concept that we have already mentioned several times as it appears in many areas of research in the economics of knowledge. Now is a time for a short discussion of it. The origin of the concept dates back to Michael Polanyi (1958), who described tacit knowledge as the part of our knowing that we are unable to communicate to others. Later on other concepts, such as know-how (vs. know that) and procedural knowledge (vs. propositional knowledge), have been used to capture the same meaning. 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 developed.

Many critics have pointed out that the seminal insight of Polanyi has been, to some extent, misrepresented (Cowan et al. 2000; Breschi & Lissoni 2001b; Brökel & Binder 2007; Perraton & Tarrant 2007). For example, is tacit knowledge uncodifiable in principle or is it simply difficult to codify (Brökel & Binder 2007, 153–154)? In fact, Wilson (2002) stresses that Polanyi's famous idea, "we know more than we can tell", implies that tacit knowledge is not only hard to convey through verbal exchange but indeed impossible. In the literature, however, tacit knowledge accounts to all and any reason for why some knowledge is not immediately communicated and become common knowledge in the society. Perraton and Tarrant (2007, 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 & 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 does not imply knowledge that is impossible to articulate. That kind of tacit knowledge can be important in some situations and, thus, deserves a concept and studies 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 learning in schools and universities would seem wasteful.

Secondly, the use of a broader than the original meaning 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 (2011b), 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 play a role when individuals attempt to assess the truthworthiness of information. We will come back to this issue in the next subsection.

3.5 Justified true belief

Until now, we have evaded the proper discussion about the concept of 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. “What constitutes knowledge?” is a question for which an entire domain of philosophy, epistemology has largely devoted to. Much is then written about the nature of knowledge and we have no hope of covering that all. Instead we need to approach the issue from the narrower perspective of the economics of knowledge. What can then epistemology offer that this discipline could use as a starting point?

Since Plato’s *Theaetetus*, epistemologists have studied knowledge on the basis of three necessary and (for the time being) sufficient conditions: S knows p if and only if

1. S believes that p,
2. S’s belief that p is justified,

3. p (i.e. it is true that p)

While there was much further discussion on the nature of these conditions, it was generally agreed that knowledge equals justified true belief. The traditional definition was ultimately challenged by Gettier (1963), when he gave the counter-examples of justified true beliefs, which we yet would not count as knowledge. These cases came to be known as the Gettier problems, and 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, 178).

The general problem with the traditional definition, which the counterexamples highlight, is that while fulfilled, the three conditions can be completely independent. This is why, for example, Nozick (1981) proposed a subjunctive condition, which requires that there is a link between the belief and its veracity. In general, three possible strategies emerged to rule out Gettier type of problems: 1) show that the counter-examples are not valid; 2) accept the counter-examples and introduce a fourth condition for knowledge that rules them out; and 3) accept the counter-examples and alter, rather than add anything, the three conditions to rule out the counter-examples (Dancy 1985, 26). It seems to be the general opinion that none of these strategies has proven completely satisfactory. First of all, Gettier's original example is quite effective and reasonable, and cannot be thus ignored. Adding or modifying the conditions has, on the one hand, produced new counter-examples and, on the other-hand, it has verged in the danger of making knowledge something that is next to impossible to achieve.

However, to quote Ancori et al. (2000), the point here is not to solve debates of other disciplines, but to point out that the given epistemological theory will affect our understanding of economic phenomena. The Gettier counter-examples showed that the traditional definition might not be sufficient for all conceivable cases, but the implication was not that the definition has lost its relevance. Despite the counter-examples, the three conditions remain necessary. Therefore, justified true belief still provides a good working definition of knowledge for economists.

To demonstrate the relevancy of justified true belief, it seems useful to first look at and then compare what working definition has usually, and mostly implicitly, been used by economists. While an all-encompassing survey is impossible, I argue that most economists either equate knowledge with true belief or just mere belief. As Faulkner and Runde (2004, 424) have noted, "mainstream microeconomic theory tends equate knowledge with true belief." As an example of "knowledge

equated with true belief” I use game theory. While Bayesian probability theory is sometimes used in game theory, the issue of what justifies beliefs is not generally discussed. In addition, Bayesian theory studies choices under uncertainty, in which agents have some prior probabilities which are then updated when new information becomes available. As such it does not concern incentives or economic justification of beliefs and is thus not discussed here further. As was said earlier, developments in game theory have induced many game theorists to study epistemic logic (see e.g. Fagin et al. 1995). To see how game theorists define knowledge, it is useful to start by looking at the knowledge axioms that are usually used in this field. These axioms were first discussed by Hintikka (1962). Similar expositions are now common in epistemic logic and game theory (e.g. Fagin et al. 1991; Aumann 1999; Samuelson 2004). This exposition is from Dekel and Gul (1997):

(K1) $K_i(A) \subset A$: if i knows A then A is true;

(K2) $K_i(A) \cap K_i(B) \subset K_i(A \cap B)$: knowing A and B is equivalent to knowing A and knowing B ;

(K3) $K_i(\Omega) = \Omega$: player i always knows anything that is true in all states of the world;

(K4) $K_i(A) \subset K_i(K_i(A))$: if i knows A then i knows that i knows that A ;

(K5) $\neg K_i(A) \subset K_i(\neg K_i(A))$: not knowing A implies knowing that A is not known.

Of these, the axioms of positive introspection (K4) and negative introspection (K5) are of our immediate interest. The idea behind these introspection axioms is that people are capable of some self-reflection: if they know something they are able to reflect that they know this; if on the other-hand they do not know something, they know that they do not. While these axioms have fallen out of favor among philosophers (Lenzen 1978; Sorensen 1988), 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. Yet, in these models, the agents know exactly the same as the economists who build the model (Faulkner & Runde 2004, 433). This approach blurs the distinction between “knowledge of the economy’s structure” and “knowledge within the structure” (Bellante & Garrison 1988, 213).

Due to (K4), agents are always aware of what they know. It is 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 in a model 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 (Stalnaker 1999; Hild et al. 1999). Connected to “agree to disagree” issues is the so-called no trade theorem (Milgrom & Stokey 1982). According to the theorem, an agent is never able to use his private information to his advantage. This is because when someone is willing to buy a stock, for example, as we can assume that they are valued similarly, at a price higher than the market price or willing to sell lower, others are able to deduce that his has received some private information and the market price is immediately adjusted accordingly. It is certainly clear that when people trade stocks they understand that their trading partners have different beliefs concerning future profits. However, the reason why trade nevertheless occurs is that they do not think that those beliefs are true, or at least as close to it as theirs. Due to the application of the axiom of positive introspection, such a scenario is not possible in these models, because each agent knows with certainty that whatever beliefs other people have or whatever information they have received is always true.

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 (see, for example, O’Driscoll & Rizzo 1985). In the case of technical knowledge, the axiom would imply that every researcher is completely aware of all the existing technologies that they do not yet know. The practical problem of course, as is the case in many of these situations, is that it is far from clear how it could be incorporated in formal economics. As such, it has been acknowledged for some time that the standard state-space model is incompatible with analyzing unawareness (Dekel et al. 1998). Without unawareness, there is no structural uncertainty in the Knightian sense, only risk. However, the problem is that 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 transfer from unawareness to awareness.

The issue that in reality people do have false beliefs has naturally not passed unnoticed. As North (2005, 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?”

The possible falsity of beliefs steers North (2005, 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, already Boulding (1966) was hesitant to use the word “knowledge” and prefers “image” to it, since it has no similar tendency to approach the meaning of truth. According to Boulding, image is something that its possessor believes to be true. However, these definitions deflate knowledge to mean both true and false beliefs, or, simply, a belief.

Considering economic phenomena, however, why would the mere accumulation of beliefs be good? Would not the truth of beliefs be at least connected to the benefits of knowing, if not the same thing as pragmatists claim? Hence, it would seem that, in general, we regard true beliefs to be ones that increase productivity, creativity or the well-being of individuals, and it is true beliefs that individuals are willing and eager to learn. In brief, our epistemic goals are to acquire as many true beliefs as possible and as few false beliefs as possible, and they are fundamentally connected with our pragmatic goals.

Once we acknowledge the possibility of false beliefs we require 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 having a true belief would be a mere accident and there would be no reason to assume that the composition of beliefs in terms of their quality (i.e. veracity) would improve over time. Furthermore, Boland (1992, 124) has argued that the existence of false beliefs should have an important role in explaining how we arrive at true beliefs.

An example of why justification is central to our discussion is given by Nozick (1981, 170). Suppose someone, who knows nothing about the matter, separately tells you and me contradictory things, which we both come to believe. By necessity, one of us has a true belief, yet few would claim that the person knows the fact. This implies that the epistemic value of communication should not be

taken as given and that more importance is to be placed on the justification of testimonial beliefs. Only then can we confidently speak of a knowledge transfer.

The issue that truthfulness cannot be directly assessed is not a reason to abandon the condition, but a reason why these considerations should be exercised. Indeed, if we were able every time to recognize true beliefs from false ones, there would be no rational explanation for why we would ever have any false beliefs. Assuming that all beliefs are necessarily true or disregarding the question of their veracity altogether would severely hinder our understanding about the important characteristics 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, which seem relevant to social epistemology, the economics of knowledge can thus yield a contribution in the form of economic epistemology (see, also, Mäki 2005). The issue of justification may become increasingly important as the key challenge in the contemporary society is no more the access to information, thanks to the Internet and ICTs more generally, but the trustworthiness of its content (Carlaw et al. 2006). So far, however, the issue of justification has received limited interest among economists.

3.6 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 & Foray 2002; Foray 2004). In particular, it has been claimed that the distinction between the concepts is what differentiates Austrian economics from mainstream economics (Boettke 2002; Metcalfe & Ramlogan 2005), as according to the former decision-makers do not just 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, 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 between these two terms. “Symposium on Information and Knowledge in Economics” was published in their 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 in the issue, it becomes clear that no common understanding about the difference between the concepts exists. Even more, the group was divided between those who regarded the distinction important for economics (Caldwell 2005; Kirzner 2005; Loasby 2005), those who did not (Aumann 2005; Yeager 2005), and those for whom it depended on the specific context in question (Mayer 2005). Roughly put, 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 practice, knowledge and information are many times used interchangeably. This practice can be seen already in the writings of Hayek and Machlup and is common to the contemporary micro theory (Foray 2004). It is easy to see why, since in the world of true beliefs and true information the distinction does not matter. If you have some particular information, it automatically implies that you know the fact presented by it, and if you know a particular fact you can always convey it 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 some knowledge 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, and due to other commitments he cannot concentrate on the

topic before the editor's (Daniel Klein) deadline. Interestingly, it would seem, as will be explained briefly, that the information paradox provides a context that Arrow had asked for.

Arrow's information paradox, as mentioned earlier, states that *ex ante* the buyer has no way of knowing the value of some particular information; it can be known only after it has been disclosed. Yet then again, the buyer has no reason to compensate the seller *ex post*. Hence, there is no effective demand for information as such.

In most cases, however, it would seem that one can describe what some information is about without revealing it. 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 (2011b), 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, i.e. the belief corresponds to a fact, and reliability whether the given information corresponds to that belief. 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 if the receiver perceives them both high enough, he has justification for adopting the belief presented by the communicated information.

As Leppälä (2011a) shows, if there are differences between capability and reliability which give the original source of the knowledge an upper-hand, this might prevent the market for information from collapsing even if there are no property rights to that information. It seems that this approach could be used to study a variety of markets for information. Furthermore, capability and reliability could yield useful insights into studying the problems in the use of expert witnesses and forensic science reports in courts (see, Koppl 2005), scientific knowledge in cases where scientific, political and economic interests are intertwined, such as the climate change debate, the role of media in the social dissemination of knowledge, or the recent problems in audition practices, such as the Enron scandal or the behavior of credit rating agencies in the recent housing market bubble.

4 FROM PERFECT KNOWLEDGE TO QUANTITY, VARIETY, AND QUALITY: SOME CONCLUDING THOUGHTS

Edith Penrose (1959, 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 issues regarding the generation, dissemination and use of knowledge surfaced from time to time, usually such considerations were omitted for the sake of relative simplicity.

It took a considerable time before the weight of that omission became noticed. As Foray (2004) argues, it was also due to the rise of knowledge economies when the issue could not be anymore avoided. In the words of Brian Loasby (1986, 41), “It is now becoming widely recognised that many of the central unresolved problems in economics turn on questions of knowledge.”

The first step to proceed in microeconomic theory was to see what happens if we relax the assumption of perfect knowledge a little bit. 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 similarly an 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 and output would be achieved?

While the issues of quantity of knowledge are naturally 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. Production 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. This explains why more diverse regions and cities produce more innovative output and are also less likely to stagnate (Desrochers & Leppälä 2011).

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. The understanding of why some institutions succeed or fail in this regard is useful in various situations considering the organization and decision-making in societies and smaller groups. 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 the most promising. Many special characteristics of knowledge as an economic good have, as we have observed, been discussed in the literature. However, these include issues such as nonrivalry, nonexcludability and cumulativeness of knowledge rather than quality by which I mean the truthworthiness of beliefs and information. I suspect that this is partly due to that “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, 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.

By ignoring the basic idea of knowledge as justified true belief, 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. However, as I have tried to argue above, it is critical. To understand why rational actors would be more likely to have true rather false beliefs, why some information is likely to be false or correct and how rational actors react to that, can only be addressed by a theory of justification. Koppl (2006) has recently provided a general theory of epistemic systems, i.e. 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, i.e. that one might receive false information, but in generation and use of knowledge as well.

The uncertainty regarding the generation of knowledge is not only that you might get no results from your efforts, but that some result may not be correct. Similarly a part of the uncertainty in decision-making comes from the fact that some beliefs on which those decisions are based on might not be true, not only from some unknown details. This is also a reason why I prefer to call the discipline the economics of knowledge, because ultimately it is the knowledge proper that we are interested in. While some discussions concentrate on a more specific issue, and there a more specific category is in place, the economics of knowledge is a useful term to convey the idea of cohesiveness among these issues. At first justification might seem like a topic of which economics has little to say about, but on the other hand the dimension of quality 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.

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 phenomenon 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, a more reasonable standard for the existence (and not the success) of a scholarly discipline is serious and widespread research, even if partially incoherent, and 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 tradition which conscious development we can easily follow through the history.

Admittedly, the omnipresence of knowledge in economic issues is both the strength and the weakness of the economics of knowledge. It leads 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. Yet, today much of the research is confined to various field journals and serious efforts to synthesize this field are few. Perhaps field journals, such as *Information Economics and Policy*, *Research Policy* and *Economics of Innovation and New Technology*, and general interest journals will help to get these strands of research together. Nevertheless, the way forward is from interaction to coherence and from coherence to general economic knowledge.

Besides the apparent fragmentation, the topics covered here overlap 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. Economics and economists have a comparative advantage addressing the incentives and institutions in the generation, dissemination and use of knowledge. This survey is far from the last word on the topic, but I see potential for many interesting and relevant paths of research ahead for economists interested in studying the role of knowledge in social systems.

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