
Working Paper Series

14/17

FROM THE ECONOMICS OF INFORMATION TO THE ECONOMICS OF KNOWLEDGE

CRISTIANO ANTONELLI

 **BRICK** Bureau of Research on Innovation,
Complexity and Knowledge



UNIVERSITÀ
DEGLI STUDI
DI TORINO

FROM THE ECONOMICS OF INFORMATION TO THE ECONOMICS OF KNOWLEDGE

Cristiano Antonelli, Dipartimento di Economia e Statistica “Cognetti de Martiis”, Università di Torino & BRICK (Bureau for Research on Innovation, Complexity and Knowledge), Collegio Carlo Alberto.

In Antonelli, C. (ed.) (2017), *Recent Developments in the Economics of Information*, Edward Elgar Research Collections, Cheltenham.

1. Introduction

In the twenty years time span from the publication in 1995 of the previous Elgar Research Collection on the topic, entitled *The Economics of Information*, edited by David K. Levine and Steven A. Lippman, the economics of information has been recognized as one of the most fertile and practiced fields of investigation in economics.

The economics of information has been able to integrate into a coherent and articulated frame the full range of disciplines into which economics specializes providing an original and innovative paradigm that has made possible an effective cooperation among distinct fields of investigation with a general increase of their analytical power. As a matter of fact the economics of information has elaborated an analytical paradigm at the same time alternative and integrative of the general equilibrium model, that has enabled to connect and reinforce the results of micro and macro investigations that were growing apart.

The award in 2001 of the Nobel Prize to Joseph Stiglitz, Michael Spence and George Akerlof testimonies the success of the research program that centers economic analysis on the study of the limits of the basic assumption shared for “more than a hundred years” that information was perfect. The Nobel Lectures of Michael Spence, Joseph Stiglitz and George Akerlof provide the best synthesis of the frontiers of economics of information and its main achievements at the crossing of the XX and the XXI centuries.

As it is the case of fertile research programs the success of information economics contains all the seeds of its evolution and transformation. Two nested processes characterize the evolution of the economics of information in this time span. First, the spreading and application of its analytical core to a variety of branches of economics from the labor economics to industrial organization, finance and monetary economics that enabled to implement and extend the original analytical core.

The stretching of this process lead to the second: the unfolding of the fertile ambiguity and ambivalence of the notion of information with the identification and eventual separation of its two basic and quite distinct meanings: knowledge and signals. There is a clear sequential causation between the two processes. The increasing scope of application of the original analytical core has led to an increasing awareness of the different facets of the very object of analysis that in turn led to restructure the focus of the original analytical core and identify two central and distinct issues:

- i) the analysis of the determinants and effects of the generation of signals;
- ii) the analysis of the determinants and effects of the knowledge that is necessary to search, screen, assess, understand, absorb, use on the one hand and to manipulate, send and hide signals on the other.

The ambiguity of the notion of information is intrinsic. The Oxford Dictionary defines information as: “*Facts provided or learned about something or someone*”. According to the Oxford Thesaurus, the synonyms of information are: “*-details, particulars, facts, figures, statistics, data -knowledge, intelligence -instruction, advice, guidance, direction, counsel, enlightenment -news, notice, word -material, documentation, documents*”. The Merriam-Webster Dictionary provides the following definition of information: *1: the communication or reception of knowledge or intelligence. 2 a (1): knowledge obtained from investigation, study, or instruction (2): intelligence, news, (3): facts, data b : the attribute inherent in and communicated by one of two or more alternative sequences or arrangements of something (as nucleotides in DNA or binary digits in a computer program) that produce specific effects c (1): a signal or character (as in a communication system or computer) representing data (2): something (as a message, experimental data, or a picture) which justifies change in a construct (as a plan or theory) that represents physical or mental experience or another construct d: a quantitative measure of the content of information; specifically: a numerical quantity that measures the uncertainty in the outcome of an experiment to be performed.*

As a matter of fact, signals and knowledge do not coincide. Signals must be emitted intentionally or dissipated accidentally or actually hidden. Agents can actually try and manipulate their signals. Signals may convey false information. Signals can engender fake knowledge. For this reason it is necessary to search, screen, sort, assess, possibly understand and finally use signals emitted by third parties to elaborate own decisions and conducts. Knowledge is indispensable to search, screen, assess and sort a signal, and most importantly, to understand it. Without prior knowledge a signal does not convey any information. A signal may be wrong and false, or actually fake. Wrong signals may be emitted accidentally by mistake: as such they disturb receivers and increase the amount of noise and consequently the need for processing, searching again and screening. Wrong signals may be emitted intentionally. Opportunistic behavior and guile may be at the origin of fake signals that are generated to alter the beliefs and knowledge of the receivers, to induce noise that increases the need for searching and screening activities and extract rents. The need for processing, searching, sorting and screening, assessing and understanding is even stronger. Fake signals, consequently, may engender barriers to entry and to mobility, increasing extraprofits for incumbents. Fake signals may induce wrong expectations and beliefs that are at the origin of actual mistakes that benefit the agents that have generated them.

Next and beyond the search of, the screening and assessment of signals become a central issue. It is not only necessary to search, screen, understand signals, but also to assess and select them so as to distinguish between true, false and fake ones. The capability to process signals and

transform them in actual information stems from the stock of competence and knowledge that individuals and organizations possess and mobilize. The success of information economics paves the way to the economics of knowledge.

The attempt of the rest of this essay is to provide a structured sequence of the steps that have shaped the transformation of the economics of information into the economics of knowledge.

2. Extensions and applications of the analytical core

The first decade of the period under consideration is characterized by a systematic extension of the range of applications and the consequent implementation of the analytical core.

As Stiglitz notes in his Nobel Lecture: “one of the main results of our research was to show that this (*the assumption of perfect information*¹) was not true; that even a small amount of information imperfection could have a profound effect on the nature of equilibrium” (Stiglitz, 2002: 461). The core of the economics of information can be defined as the analysis of the consequences of the imperfection of information. The basic claim of the economics of information is that information imperfections cannot be reduced to transaction cost as they have far deeper effects in terms of the incentives and mechanisms that information asymmetries engender. The analysis of the distribution of information enabled the discovery of

¹ Author's inclusion.

information asymmetries with all the implications in terms of differentiation of the incentives and conducts between agents according to their conditions of access information: incentives to access information and incentives to hold it. Actions in markets characterized by information imperfections convey information that affects the conduct of agents, their interaction and coordination and (multiple) equilibrium solutions.

The depth and ingenuity of the analytical core of information economics stirred an array of fruitful applications in a variety of contexts that enabled the enrichment of the analytical core with important contributions. Riley (2001) updates the main contributions to the economics of information with a systematic review of the classic issues identified in the first stage of implementation of the analytical core: principal-agent relations, moral hazard, hidden knowledge and adverse selection, screening and search processes, signaling and their applications in labor economics, industrial organization, theory of the firm, finance. The array of specific applications of the analytical core leads to the introduction of actual extensions and implementations.

Arrow (1996) identifies the sharp difference between its elaboration and transmission costs as a key characteristic of information and explores its consequences for firms and markets and the economy at large. Once generated, information can be reproduced and applied to large quantities of products at negligible marginal costs. Average information costs share the basic characteristics of average fixed costs that exhibit a negative slope. The exclusive command of information is at origin of increasing returns

based on typical economies of density that engender systematic departures from competitive equilibrium in both product and factor markets. Firms have strong incentives not only to generate information but also to retain its control and to avoid its dissemination. As a consequence both the generation and the control of information become a central element of firms strategies. The effects of the difference between its generation and transmission and application costs are at the origins of intentional and persistent information asymmetries between agents. Information asymmetries are endogenous to the economic system.

The investigation of the mechanisms of the generation and dissemination of information become progressively the central issue. In this context reputation attracts much attention. Reputation, in fact, is itself a signal that conveys information on the quality of goods. The higher the reputation of a seller, the higher the expected quality of its goods and hence the higher the prices sellers can charge. Reputation is an important informational asset. The creation of reputation is itself the result of an intentional economic activity: forward looking agents act intentionally to establish a reputation that will yield a marginal revenue. Actions that undermine the reputation are likely to have long-lasting dangerous and negative consequences. The defense of reputation is consequently important. McLeod (2007) provides a of the comprehensive survey of the literature on contract enforcement centered on the role of reputation as a e reliable signal of the quality of products and a detailed analysis of the wide range of alternative mechanisms to induce providers of goods to stick to the expected levels of quality of their products. Quite often reputational

signals do not convey the correct information with the risk that the quality anticipated on a reputational base does not meet the actual characteristics of the products delivered.

Reputation is by definition a non-ergodic process whereby the signals emitted by an agent in the past display their effects in the present and in the future. Reputation is a path dependent, rather than past dependent process: events that take place at each point in time do modify the reputation, but the amount of efforts and time that are necessary to alter the original information is significant. The consequences of the path dependent character of reputation are far reaching. According to a prevailing strand of literature (Holmstrom, 1999) the economic value of the reputational capital of an agent with long-run interests exerts short-run commitments and can thereby substitute for explicit contractual enforcement. Ely and Valimaki (2003) elaborate a model to explore the perverse implications of reputation where the concern of a forward looking agent for his reputation puts at stake his commitment power and leads to the loss of all surplus. Their model capsizes the pervasive idea shared by much information economics that the quest for reputation is compatible with equilibrium.

Blundell and Stoker (2005) provide an instructive synthesis of the literature that explores the consequences of the informational heterogeneity of agents. The irreducible heterogeneity of agents is an important implication of the notion of information asymmetries. Standard economics of Marshallian ascent assumes that heterogeneity, at least on

the supply side, can take place but only as a contingent market imperfection. The competitive process sweeps out least efficient firms and reestablishes homogeneity. Horner (2009) shows that market selection does not necessarily lead to efficient solutions. When heterogeneity does not stem from the use of less efficient techniques or simply mistakes, but is the consequence of information asymmetries and market imperfections, the market selection may fail to sort out less efficient firms so as to re-establish an equilibrium condition: less efficient but better informed firms may outperform better firms that miss the correct amount and quality of information. The process leads to spurious heterogeneity that undermines the legitimacy of the aggregation procedures that are indispensable for expanding economic analysis beyond the limits of the study of individual action.

Dewatripont and Tirole (2005) explore another crucial implication of the economics of information: the cost of communicating signals and its implication for moral hazard. Dewatripont and Tirole (2005) distinguish three types of information: hard information that can be verified by the receiver, soft information that cannot be substantiated and an intermediate layer where the information received requires dedicated efforts in terms of attention, decoding, understanding and rehearsing. They claim that the intermediary case, between the two extreme ones, is by far the most relevant. The success of information depends on the alignment of the parties' objectives and is influenced by reputation and credibility. These premises enable to show that informational failures can easily take place as well as virtuous cycles of intense communication in a general context

characterized by strong path dependence. The communication process exhibits all the characteristics of a non-ergodic path dependent dynamics where at the same time the past matters but the dynamics can be altered significantly by events along the process.

The enquiry on information asymmetries reveals a crucial aspect: agents differ not only with respect to the amount and quality they actually command, receive and send, but also with respect to the costs incurred to access the necessary amount and quality of information. Some agents are better informed than others and have easier access to further information. The investigation is consequently directed to grasp the determinants of such asymmetries in the access and use of information. Three lines of enquiry have been implemented to answer this question: i) the access modes to information; ii) the context of access, and iii) the capability to process information. This third line of enquiry leads directly to the eventual implementation of the economics of knowledge.

The modes of acquisition of information play a crucial role. The access to information is the result of search activities that consist in screening the signals generated by the agents in the system. Rogerson, Shimer and, Wright (2004) synthesize the main achievements of the literature on search models. The literature on the characteristics of the search process highlights their variety as well as their basic problem i.e. the identification of the correct matching between the specific competence and quality of the demand and the supply side respectively. Both suppliers and customers are afflicted by the lack of detailed and specific information on the

characteristics of the products and services that are necessary. Job matching is especially investigated as the field where the imperfections of information are most relevant and the search takes place on both sides. The perverse effects of opportunistic behavior and intentional dissemination of false information affects heavily search activities: trust is an important ingredient of the search process as it reduces the cost. The reliability of the information is influenced by the levels of trust that each agent can attribute to its source (Karlan, Mobius, Rosenblat, Szeidl, 2009). The literature on information search confirms the limits of current assumptions about the rationality of agents involved and stresses the role of herd behaviors. The costs of search and its failure are often so high that even privately informed agents try and extract additional information from the analysis of the behavior and beliefs of agents with whom each of them is connected Banerjee (1992). The consequences of herd behavior are important: fads are fed by the informational cascades that most often account for the consolidation of “post truth” rather than truth.

The context into which agents are localized has been regarded and analyzed as the first and main cause of information cost asymmetries. Agents access information by means of a variety of combinations that are comprised between the two extremes of pure interactions and pure transactions. Transactions-cum-interactions are the actual carriers of information. Agents can extract limited information from pure, spot and impersonal transactions. Transactions are carriers of much information when they take place between identified agents, are repeated over time, are paralleled by appropriate levels of trust between the parties involved and

imply some direct interactions. In turn, personal interactions among agents are relevant vectors of information. The identification of the economic context where the array of transactions-cum-interactions takes place leads to the discovery of the central role of networks.

The access to information is asymmetric because of the asymmetric role of each agent in the networks of exchanges, transactions and interactions that relate each agent to the others. Networks, both within markets and between markets, integrated by personal interactions, are the actual mechanisms that enable the access and screening of information as they parallel the flows of information with the trust that stems from reciprocity and exposition to the risks of punishment in terms of exclusion. Ioannides and Datcher Loury (2004) explore the role of the social structure of connections among individuals as the basic source of information. Informal relations among individuals are structured by specific architectures that influence heavily the search process. Search does not take place on a one-to-one basis, but through the informal connections that relate each individual to many others. Karlan, Mobius, Rosenblat and Szeidl (2009) explore the role of the density of networks as the source of bonding social capital that allows transacting valuable assets. Strong ties between employers and trusted recommenders reduce information asymmetries in the job markets about the quality of potential employees. Jackson (2014) and Young (2009) provide quite a comprehensive analysis of the characteristics of networks and their effects on economic systems. The density, segregation patterns, homophily and the position of each agent within each network in terms of centrality, the variety of connecting

nodes, the clustering of interactions shape the distribution of information and its access costs among the agents and have powerful effects on the actual access to information of their members. These characteristics of networks consequently shape the distribution of information across economic systems and exert relevant effects not only at the agent level but also at the system level. The performances of economic systems reflect the characteristics of the architecture of and participation to the networks that are structural ingredient of the system. The origins of networks becomes themselves a relevant object of investigation: Jackson (2014) questions the standard assumptions and put forward the hypothesis that networks are endogenous: their size and structure is the result of the accumulation through time of the participation and action of agents. Non ergodic path dependent dynamics is again at work.

The analysis of the procedures and mechanisms by means of which signals are searched, screened and accessed by agents enables to appreciate the extent to which signals may be wrong or fake. Bikhchandani, Hirshleifer, and Welch (1992) explore the mechanisms of information cascades. Agents try and extract information from the behavior of other agents and the interaction with other agents that are qualified in terms of trust and reliability. The process is at the origin of localized conformity: all the agents that belong to a community eventually share basic beliefs that may happen to be wrong. The process has intrinsic dynamic properties by means of which the original belief appears stronger and stronger as social sharing takes place and gains momentum. The dynamics is characterized by typical herd behavior (Banerjee, 1992). This dynamics leads to the

emergence and eventual, frequent, failure of fads and fashions. As far as the preferences of consumers are concerned there is ground to claim that signals were wrong. When herd behavior applies to supply side events, the actual content of information becomes relevant. Information cascades in financial markets may eventually lead to crashes and financial crisis because the social sharing had constructed and reinforced false information. The lack of appropriate assessment and the related capabilities leads far away from equilibrium.

The analysis of information cascades has been primarily and mainly implemented on the receivers side, and little explored on the emitting side. Benabou and Laroque (1992) explore the implications of information cascades from the viewpoint of the intentional emission of wrong signals designed to take full advantage of informational cascades in order to manipulate markets. The use of privileged information and gurus with high levels of reputation, well connected into networks with high levels of homophily, are typical tools of the intentional construction of information cascades to make profits. Benabou and Laroque (1992) provide one of the most effective analyses of the incentives to use noisy private signals to manipulate strategically financial markets that has not received the appropriate amount of consideration.

Information economics seems to re-discover the epidemic approach to the diffusion of innovation established in the economics of innovation since the late fifties of the XX century (Griliches, 1957). Zvi Griliches had already identified the burden of the assessment of the actual characteristics

of new products and processes as the critical factors that account for the delay in the adoption of superior products, either final or capital and intermediary. Cautious potential customers, unable to assess directly and individually the new products, rely upon the information extracted from the experience of early users. The decision to adopt a new product is based upon the interaction with other users that have already tested the new products. The process shares the basic characteristics of contagion where by successive groups of potential customers, characterized by declining levels of individual competence, discover the actual advantages provided by the new products not directly but indirectly by means of the extraction of information made reliable and intelligible by the conduct of other agents better able to grasp them. The large empirical evidence of the economics of epidemic diffusion shows that early users are characterized by higher levels of competence, skills, human capital and experience. The rationality of early users is less bounded than the rationality of late users (Mansfield, 1961).

Much economics of information seems busy to implement a neo-epidemic approach to understanding the role of information in the dynamics of decision-making that generalizes to the wide range of economic actions the early understanding of the role of imitation in the diffusion of innovations – the puzzle of the delayed adoption of new superior goods- as a mechanism to cope with the intrinsic bounded rationality of economic agents, that had been explored a few decades before by the economics of innovation.

This generalization, seemingly unaware of its antecedents, has, however, important merits as it enabled: i) to better explore the role of the organization and the structure of the system into which the epidemic contagion takes place with the systematic application of new tools such as network theory and information cascades; ii) to confirm the role of interactions as carriers to tacit knowledge; and iii) to show the general relevance of the limits of individual decision making, of the crucial role of knowledge, and of the procedural and collective mechanisms that seemed to apply only to a specialized and extreme set of circumstances such as the appreciation of the merits of new and unknown products and processes.

The appreciation of the role of endogenous information asymmetries in shaping decision making and conduct of agents enables to make progressively explicit the tacit assumption about the bounded rationality of economic agents that has characterized the early stages of the economics of information. It becomes clearer and clearer, in fact, that information asymmetries and the procedures and mechanisms that enable to access and use information are actually relevant because of the bounded rationality of economic agents (Simon, 1982). Economic agents effectively endowed with the Olympian rationality assumed in basic microeconomics would be able to assess directly and individually their choices and identify optimal solutions.

The sharp difference between the cost of accessing information and the costs of processing it, identified by Kenneth Arrow as the key characteristics of information, is back to the center stage and enables to

operationalize the notion of bounded rationality introduced by Herbert Simon.

Customers, consumers, employees, and employers, savers and investors, as well as producers –not just adopters- actually able to access and assess directly and individually all the relevant information about the objects and the nature of their choices and conducts would not need to try and gauge indirect information from the behavior of other agents and to extract it from the interaction with other agents that are qualified in terms of trust and reliability. Because of bounded rationality, instead, agents, aware of high costs of information processing, rely upon the procedural rationality that consists in limiting the amount of information that it is necessary not only to access but also and primarily to screen and process, by means of the selective imitation of reliable agents. Trust complements bounded rationality and enables to implement the procedural rationality that helps reducing the costs of information processing.

The understanding of the central role of the implicit and little explored role of bounded and procedural rationality, as opposed to Olympian rationality, at the foundations of the economics of information has two important consequences.

First, decision making is no longer exclusively individual: a strong collective dimension plays a central role. Decision making takes place at the individual level but it is the result of the recursive interaction between the characteristics, the organization and the structure of the system into

which each agent is localized and the individual choices. Each dimension interacts with the other and engenders a dynamic process.

Second, the exploration of the determinants and consequences of the conditions and characteristics of the processes that underlie the generation, use and distribution of knowledge is the necessary step forward of the economics of information.

3. Towards the economics of knowledge

The second decade of the period under consideration is characterized by the progressive shift from an economics of information more and more aware of the role of knowledge as the necessary screening device that performs the role of transforming of signals into information to a full fledged economics of knowledge applied to much a wider set of problems than the original cradle centered upon the investigation of the characters, origins and consequences of scientific and technological knowledge.

As Stiglitz notes knowledge matters because agents have incentives not only to access and to hide information, but also to create it: “While early work in the economics of information dealt with how markets overcome problems of information asymmetries, later work turned to how actors in markets *create* information problems, for example in the attempt to exploit market power” (Stiglitz, 2002:470). The awareness of the informational effects may lead agents to act purposely. As a consequence, on the receiver side, screening must take into account the deliberate intention of the sources of the signals that are emitted to distort the behaviors and beliefs

of receivers. Signals may be fraudulent. Not only screening, but also examination and monitoring are necessary to assess them. Fake signals may be generated intentionally to create barriers to entry and to mobility, increasing extraprofits for incumbents. Fake signals may be created and disseminated intentionally to induce wrong decisions and conducts that are at the origin of actual profits for the agents that have generated them. The conclusion of this analysis is clear: if information asymmetries and information imperfections are endogenous, knowledge is necessary to transform signals into information.

Knowledge is the capability to sort, process, assess and make sense of the data and signals that qualify and parallel economic action providing their necessary selection, the exclusion of false signals, the integration of reliable ones into the stock of existing information so as to provide additional information on the state of economic affairs. Knowledge consists primarily in connecting scattered elements and bits and transforming them into an intelligible set of reliable information that guide economic action. The Bayesian definition of technological knowledge elaborated by Arrow applies to knowledge in general:

A more general formulation including both research and learning by doing can be formulated and will, I think, be useful. The Bayesian language will be used (for an excellent introduction, see Raiffa [11, Chaps. 1–5]); however, any sensible analysis of uncertainty will lead to equivalent formulations. Let the term “activity” be used, as usual for any process described by inputs and outputs, but we are particularly interested in the case where the outputs are not known with certainty. It can easily happen that the outcomes for different activities will be dependent random variables in the sense of a subjective probability. The case most interesting from the present point of view is that where there is an underlying unknown parameter upon which the probability distributions of outcomes for the different activities depend; then observing the outcome of one activity changes the *a posteriori* distribution of outcomes of the other. This need not happen of course; if the outcome of an activity is known with certainty a priori, then observing the outcome cannot change the probabilities of outcome of any other activity. More generally, if there is statistical independence between the outcomes of activities, the probability of distribution of the outcomes of one is unaffected by observations on the outcomes of another. Thus, if I really believe a pair of dice is fair, observing any outcome is of no use in predicting a subsequent one. But if I suspect bias and I express my suspicions by an appropriate subjective probability distribution over the possible outcomes, then observing an outcome certainly does change my subsequent expectations in accordance with Bayes’s theorem.

Arrow (1969: 30-31)

The economics of knowledge becomes the new frontier of the economics of information.

From this viewpoint the economics of knowledge provides the platform into which the economics of information and the economics of innovation seem to converge. The economics of scientific and technological knowledge in fact developed as the outcome of the economics of innovation and technological change and been specializing in the investigation of the processes that characterize the generation and exploitation of scientific and technological knowledge. The economics of technological and scientific knowledge provides the basic tools to grasp the processes by means of which new knowledge is being generated and applied to economic activities. In so doing the economics of technological knowledge provides the analytical platform that can accommodate the understanding of the persistent heterogeneity of agents, the feedbacks between knowledge and innovation, the increase of economic efficiency. To-day the economics of technological knowledge can be regarded as the ultimate step of a backward process of investigation that has been moving from the economics of technical change, to the economics of technological change and economics of innovation (Link and Antonelli, 2014).

The convergence of the economics of information and the economics of innovation into the broader platform of the economics of knowledge leads to a richer field of investigation far more comprehensive and inclusive than the economics of technological knowledge. Next to technological and scientific knowledge, commercial knowledge is a crucial issue as much as financial and organizational knowledge, and more generally knowledge

about the preferences and behaviors of consumers, savers, investors, workers and competitors. The implications of the new economics of information augmented into a full-fledged economics of knowledge are most important not only for the theory of the firm and the theory of markets, but for economics at large. The augmented economics of knowledge applies is emerging as an inclusive field of investigation that applies to the full range of economic activities from labor economics to industrial organization, finance on both the supply and the demand side, including the economics of innovation and its applications to science and technology.

The advances and acquisitions of the economics of scientific and technological knowledge are being more and more generalized, shared and merged within a broader and augmented economics of knowledge that includes the wide array of specific forms of economic information and knowledge. The process enables to take advantage of the achievements of the economics of technological and scientific knowledge based upon the Arrowian analysis of the properties of knowledge as a “special” economic good characterized by:

- i) limited appropriability and excludability, negligible reproduction cost;
- ii) limited exhaustibility with its important consequences in terms of cumulability and complementarity;
- iii) powerful effects in terms of distorted incentives and the sweeping array of positive and negative externalities;
- iv) the central role of learning by doing, by using and by interacting in its generation;

- v) the complementarity between internal and external sources of knowledge in the recombinant generation of new knowledge;
- vi) the distinction between tacit and codified knowledge and
- vii) the related central role of interactions as indispensable mechanisms to acquire and transfer knowledge intrinsically characterized by an irreducible tacit content,
- viii) the relevance of communication problems on both the emitting and the receiving sides (Antonelli and Link, 2015; Antonelli and David, 2016).

Samuelson fully acknowledges the new role of the augmented economics of knowledge and its direct relationship with the economics of information stressing the central role of economic knowledge in the core issues of the economics of information: “It is now clear that much of economic importance depends upon what people know. A monopolist who knows the valuations of her customers may practice first-degree price discrimination, earning more than a monopolist constrained by ignorance to uniform pricing. Bargaining between buyer and seller may lead to an efficient outcome if both know the others’ valuations (Ariel Rubinstein 1982), but must sometimes be inefficient if both are uncertain (Roger Myerson and Mark Satterthwaite 1983). Risk-averse workers may be perfectly insured by risk-neutral firms if the latter know the effort exerted by the former, but may otherwise be exposed to risk in order to create incentives. Competitive insurance markets may function well if insurers know the risk characteristics of their clients, but may exhibit no equilibrium if these are unknown (Michael Rothschild and Joseph Stiglitz 1976). The list goes on.” (Samuelson, 2004: 368).

Bo Carlsson and Gunnar Eliasson (1994) provide an excellent introduction to an extended economics of knowledge highlighting the need for agents to possess the competence that is necessary to assess and use information in a broad variety of economic activities. The appreciation of the central role of knowledge as the necessary interface that enables to transform signals into actual information in turn raises the research issue of its origins and determinants. The mechanisms by means of which knowledge is acquired and used by individuals and organization is the consequent step forward.

Building upon the intuition by Bolton and Dewatripont (1994) that analyze the firm as a communication network, the firm is more and more viewed as a communication network and a nexus of knowledge interactions. The firm is the privileged locus of knowledge interactions: the size and variety of activities of the firm are determined by the knowledge interactions that are necessary for the generation of tacit knowledge that enables the absorption of signals, their transformation in information and knowledge, their eventual application for the production of goods. The size and scope of activity of the firm is limited by the costs of internal coordination. The organization of firms can be analyzed as a mechanism that is designed to combine the generation of specific knowledge together with the use of general knowledge (Garicano, 2000). A clear trade-off takes place between the economic value of the knowledge generated by means of internal knowledge interactions and the cost of hierarchical coordination and administration (Lam, 2000; Garicano and Wu, 2012).

Outside the firm, knowledge interactions play a crucial role as they parallel and complement transactions. The wide spectrum of transactions-cum-knowledge-interactions characterized by personal ties, recurrence, reputation and trust opens wide between the two extremes of spot, single and impersonal transactions and the hierarchical coordination of internal interactions within the boundaries of firms. Networks, as structured systems of organized knowledge interactions, become a relevant unit of analysis. This approach enables to understand the endogenous emergence of networks as structured systems of interactions among agents that search complementary pieces of information (Cowan and Jonard, 2004).

As Blundell and Stocker (2005) note, the central role of knowledge in economics opens the issue of the intrinsic heterogeneity of agents and consequently makes clear the failure of the representative agent assumption as a plausible and consistent assumption to analyze the working of the system. The market place appears more and more as an institutional system shaped by non-ergodic processes, rather than the rational outcome designed by the search for general equilibrium, where, more or less, effective, rather than efficient, transactions can take place between privately informed buyers and sellers (Loertscher, Marx, Wilkening, 2015).

Landini, Gallegati and Stiglitz (2015) explore the implications of interaction among learning agents in terms of regenerative coordination by means of which firms select their price and output strategies taking into

account their consequences in terms of learning opportunities: firms become fully aware of the implications of learning-to-learn.

Kirman (1997 and 2011) shows the implications, at the system level, of the interaction of heterogeneous learning agents that possess different and changing levels of knowledge. The structure of economic systems consisting in their institutional and organizational apparatus appears as the main scaffolding mechanism that enables the coordination of the variety of heterogeneous agents that interact within and along the multiple market places that constitute an economic system (Colander, Howitt, Kirman, Leijonhufvud, Mehrling, 2008).

4. References

Akerlof, George A. (2002), "Behavioral Macroeconomics and Macroeconomic Behavior", *American Economic Review* 92(3): 411-433.

Antonelli, Cristiano, Link, Albert N. (eds.) (2015), "*Handbook on the Economics of Knowledge*", Routledge, London.

Antonelli, Cristiano, David, Paul A. (eds.) (2016), "*The Economics of Knowledge and Knowledge Driven Economy*", Routledge, London.

Arrow, Kenneth J. (1969), "Classificatory Notes on the Production and Transmission of Technical Knowledge", *American Economic Review* 59, 29-35.

Arrow, Kenneth J. (1996), "The Economics of Information: An Exposition", *Empirica* 23 (2) pp. 119-128.

Banerjee, Abhijit V. (1992), "A Simple Model of Herd Behavior", *Quarterly Journal of Economics* 107 (3), pp. 797-817.

Benabou, Roland, Laroque, Guy (1992), "Using Privileged Information to Manipulate Markets: Insiders, Gurus, and Credibility," *Quarterly Journal of Economics* 107 (3), pp. 921–958.

Bikhchandani, S., Hirshleifer, D., Welch, I. (1992), "A Theory of Fads, Fashion, Custom and Cultural Change as Informational Cascades", *Journal of Political Economy* 100 (5), pp. 992-1026.

Bolton, Patrick, Dewatripont, Mathias (1994), “The Firm as a Communication Network.” *Quarterly Journal of Economics* 109 (November), pp. 809–39.

Blundell, Richard, Stoker, Thomas M. (2005), “Heterogeneity and Aggregation”, *Journal of Economic Literature* 43 (2) pp. 347-391.

Carlsson, Bo, Eliasson, Gunnar (1994), “The Nature and Importance of Economic Competence.” *Industrial and Corporate Change* 3 (3): 687-711.

Colander, David, Howitt, Peter, Kirman, Alan, Leijonhufvud, Axel, Mehrling, Perry (2008), “Beyond DSGE Models: Towards an Empirically Based Macroeconomics.” *American Economic Review* 98 (2), pp.236-240.

Cowan, Robin, Jonard, Nicolas (2004), “Network Structure and the Diffusion of Knowledge.” *Journal of Economic Dynamics and Control* (28) 1557-1575.

Dewatripont, Mathias, Tirole, Jean (2005), “Modes of Communication.” *Journal of Political Economy* 113 (6), pp. 1217-1238.

Ely, Jeffrey C., Valimaki, Juuso (2003), "Bad Reputation" *Quarterly Journal of Economics* 118(3), 785-814.

Garicano, L. (2000), “Hierarchies and the Organization of Knowledge in Production”, *Journal of Political Economy* 108(5):874–904.

Garicano, L., Wu, Yanhui (2012), “Knowledge, Communication, and Organizational capabilities”, *Organization Science* 23 (5):1382–1397.

Griliches, Zvi (1957), Hybrid Corn: An Exploration in the Economics of Technological Change”, *Econometrica* 25 (4): 501–22.

Holmstrom, Bengt (1999), “Managerial Incentive Problems: A Dynamic Perspective.” *Review of Economics Studies*, LXVI (1999), 169–182.

Horner, Johannes (2002), "Reputation and Competition." *American Economic Review* 92(3), pp. 644-63.

Ioannides, Yannis M., Datcher Loury, Linda (2004), “Job Information Networks, Neighborhood Effects, and Inequality.” *Journal of Economic Literature* 42(4) pp. 1056–1093

Karlan, Dean, Markus, Mobius, Tanya, Rosenblat, Szeidl, Adam (2009), “Trust and Social Collateral.” *Quarterly Journal of Economics* 124 (3): 1307–61.

Kirman, Alan (1997), “The Economy as an Evolving Network”, *Journal of Evolutionary Economics* 7, pp. 339-353.

Kirman, Alan (2011), “Learning in Agent-based Models”, *Eastern Economic Journal* 37 (1) 20-27.

Jackson, Matthew O. (2014), “Networks in the Understanding of Economic Behaviors”, *Journal of Economic Perspectives* 28 (4) pp. 3–22.

Lam, Alice (2000), “Tacit Knowledge Organizational Learning Societal Institutions: An Integrated Framework”, *Organizational Studies* 21 (3), pp. 487-513.

Landini, Simone, Gallegati, Mauro, Stiglitz, Joseph E. (2015), “Economies with Heterogeneous Interacting Learning Agents”, *Journal of Economic Interaction and Coordination* 10 pp. 91-118.

Link, Albert N., Antonelli, Cristiano (eds.) (2014), “*Recent Developments in the Economics of Science and Innovation*”, Edward Elgar International Library of Critical Writings in Economics (founding editor Professor Mark Blaug), Cheltenham.

Loertscher, Simon, Marx, Leslie M., Wilkening, Tom (2015), “A Long Way Coming: Designing Centralized Markets with Privately Informed Buyers and Sellers”, *Journal of Economic Literature* 53(4), 857–897.

MacLeod, W.B. (2007), “Reputations Relationships and Contract Enforcement”, *Journal of Economic Literature* 45 (3), pp. 595-628.

Mansfield, Edwin (1961), “Technical Change and the Rate of Imitation”, *Econometrica*, 29 (4) (1961), pp. 741–766

Riley, John, G. (2001), “Silver Signals: Twenty-Five Years of Screening and Signaling”, *Journal of Economic Literature* 39 (29), pp. 432-478.

Rogerson, Richard, Shimer, Robert, Wright, Randall (2004), “Search-Theoretic Models of the Labor Market: A Survey”, *Journal of Economic Literature* 42 (4), pp. 959-988.

Samuelson, Larry (2004), “Modeling Knowledge in Economic Analysis”, *Journal of Economic Literature* 42 (2), pp. 367-403.

Simon, Herbert A. (1982), “*Metaphors of Bounded Rationality. Behavioral Economics and Business Organization*”, MIT Press, Cambridge.

Spence, Michael (2002), “Signaling in Retrospect and the Informational Structure of Markets”, *American Economic Review* 92 (3), pp. 434-459

Stiglitz, Joseph E. 2000. "The Contributions of the Economics of Information to Twentieth Century Economics," *Quarterly Journal of Economics* 115 (4), pp. 1441-1478.

Stiglitz, Joseph E. 2002. "Information and the Change in the Paradigm in Economics," *American Economic Review*, 92(3) pp.406-501.

Young, Peyton H. (2009), "Innovation Diffusion in Heterogeneous Populations: Contagion, Social Influence, and Social Learning", *American Economic Review* 99(5), pp. 1899-1924.

CONTENTS

I. INTRODUCTION

1. Antonelli, Cristiano, From the Economics of Information to the Economics of Knowledge.

II. THE STATE OF THE ART

2. Spence, Michael (2002), "Signaling in Retrospect and the Informational Structure of Markets", *American Economic Review* 92 (3), pp. 434-459.

3. Akerlof, George A. (2002), "Behavioral Macroeconomics and Macroeconomic Behavior" *American Economic Review*, 92(3): 411-433.

4. Stiglitz, Joseph E. 2002. "Information and the Change in the Paradigm in Economics," *American Economic Review*, 92(3) pp.406-501.

III. APPLICATIONS AND EXTENSIONS

5. Riley, John, G. (2001), “Silver Signals: Twenty-Five Years of Screening and Signaling”, *Journal of Economic Literature* 39 (29), pp. 432-478.
6. Arrow, Kenneth J. (1996), “The Economics of Information: An Exposition”, *Empirica* 23 (2) pp. 119-128.
7. MacLeod, W.B. (2007), “Reputations Relationships and Contract Enforcement”, *Journal of Economic Literature* 45 (3), pp. 595-628.
8. Holmstrom, Bengt, (1999), “Managerial Incentive Problems: A Dynamic Perspective.” *Review of Economics Studies*, LXVI (1999), 169–182.
9. Ely, Jeffrey C., Valimaki, Juuso (2003), "Bad Reputation" *Quarterly Journal of Economics* 118(3), 785-814.
11. Horner, Johannes (2002), "Reputation and Competition." *American Economic Review* 92(3), pp. 644-63.
12. Dewatripont, Mathias, Tirole, Jean (2005), “Modes of Communication.”, *Journal of Political Economy* 113 (6), pp. 1217-1238.

13. Rogerson, Richard, Shimer, Roberet, Wright Randall (2004), “Search-Theoretic Models of the Labor Market: A Survey”, *Journal of Economic Literature* 47 (4), pp. 959-988.
14. Karlan, Dean, Markus Mobius, Tanya Rosenblat, Szeidl, Adam (2009), “Trust and Social Collateral.” *Quarterly Journal of Economics* 124 (3): 1307–61.
15. Banerjee, Abhijit V. (1992), “A Simple Model of Herd Behavior”, *Quarterly Journal of Economics* 107 (3), pp. 797-817.
16. Ioannides, Yannis M., Datcher Loury, Linda (2004), “Job Information Networks, Neighborhood Effects, and Inequality.” *Journal of Economic Literature* 42(4) pp. 1056–1093.
17. Jackson, Matthew O. (2014), Networks in the Understanding of Economic Behaviors, *Journal of Economic Perspectives* 28 (4) pp. 3–22.
18. Young, Peyton H. (2009), “Innovation Diffusion in Heterogeneous Populations: Contagion, Social Influence, and Social Learning”, *American Economic Review* 99(5), pp. 1899-1924.
19. Bikhchandani, S., Hirshleifer, D., Welch, I. (1992), “A Theory of Fads, Fashion, Custom and Cultural Change as Informational Cascades”, *Journal of Political Economy* 100 (5), pp. 992-1026.

20. Benabou, Roland, Laroque, Guy (1992), “Using Privileged Information to Manipulate Markets: Insiders, Gurus, and Credibility,” *Quarterly Journal of Economics* 107 (3), pp. 921–958.

IV: TOWARDS THE ECONOMICS OF KNOWLEDGE

21. Stiglitz, Joseph E. 2000. "The Contributions of the Economics of Information to Twentieth Century Economics," *Quarterly Journal of Economics* 115 (4), pp. 1441-1478.

22. Arrow, K. J. (1969), Classificatory notes on the production and transmission of technical knowledge, *American Economic Review* 59, 29-35.

23. Samuelson, Larry (2004), “Modeling Knowledge in Economic Analysis”, *Journal of Economic Literature* 47 (2), pp. 367-403.

24. Carlsson, Bo, Eliasson, Gunnar (1994), “The Nature and Importance of Economic Competence.” *Industrial and Corporate Change* 3 (3): 687-711.

25. Bolton, Patrick, Dewatripont, Mathias (1994), “The Firm as a Communication Network.” *Quarterly Journal of Economics* 109 (November), pp. 809–39.

26. Garicano, Luis (2000), “Hierarchies and the Organization of Knowledge in Production”, *Journal of Political Economy* 108(5):874–904.
27. Lam, Alice (2000), “Tacit Knowledge Organizational Learning Societal Institutions: An Integrated Framework”, *Organizational Studies* 21 (3), pp. 487-513.
28. Garicano, Luis, Wu, Yanhui (2012), “Knowledge, Communication, and Organizational capabilities”, *Organization Science* 23 (5):1382–1397.
29. Cowan, R., Jonard, N. (2004), “Network Structure and the Diffusion of Knowledge.” *Journal of Economic Dynamics and Control* (28) 1557-1575.
30. Blundell, Richard, Stoker, Thomas M. (2005), “Heterogeneity and Aggregation”, *Journal of Economic Literature* 43 (2) pp. 347-391.
31. Loertscher, Simon, Marx, Leslie M., Wilkening, Tom (2015), “A Long Way Coming: Designing Centralized Markets with Privately Informed Buyers and Sellers”, *Journal of Economic Literature* 53(4), 857–897.

- 32. Landini, Simone, Gallegati, Mauro, Stiglitz, Joseph E. (2015), “Economies with Heterogeneous Interacting Learning Agents”, *Journal of Economic Interaction and Coordination* 10 pp. 91-118.**
- 33. Kirman, Alan (1997), “The Economy as an Evolving Network”, *Journal of Evolutionary Economics* 7: 339-353.**
- 34. Kirman, A. (2011), “Learning in Agent-based Models”, *Eastern Economic Journal* 37 (1) 20-27.**
- 35. Colander, David, Howitt, Peter, Kirman, Alan, Leijonhufvud, Axel, Mehrling, Perry (2008), “Beyond DSGE Models: Towards an Empirically Based Macroeconomics.” *American Economic Review* 98 (2), pp.236-240.**