The Knowledge Economy:
Fritz Machlup's Construction of a Synthetic Concept

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Abstract

In 1962, the economist Fritz Machlup published an influential study that measured the production and distribution of knowledge in the United States. Machlup's calculations gave rise to a whole literature on the knowledge economy, its policies and its measurement. Today, the knowledge-based economy or society has become a buzzword in many writings and discourses, both academic and official. Where does Machlup's concept of a knowledge economy come from? This paper looks at the sources of Machlup's insight. It discusses how *The Production and Distribution of Knowledge in the United States* is a work that synthesizes ideas from four disciplines or fields of research – philosophy (epistemology), mathematics (cybernetics), economics (information) and national accounting – thus creating an object of study, or concept for science policy, science studies and the economics of science.

The Knowledge Economy:
Fritz Machlup's Construction of a Synthetic Concept [1]

According to many authors, think tanks, governments and international organizations, we now live in a knowledge-based economy. Knowledge is reputed to be the basis for many if not all decisions, and an asset to individuals and firms. Certainly, the role of knowledge in the economy is not new, but knowledge is said to have taken increased importance in recent years, both quantitatively and qualitatively, partly because of information and communication technologies. [2]

The concept of a knowledge economy comes from Fritz Machlup. In 1962, the Austrian-born economist published a study that measured the production and distribution of (all kinds of) knowledge in the United States. [3] The author estimated that, in 1958, the knowledge economy accounted for $136.4 million or 29% of GNP. Machlup was the first to measure knowledge as a broad concept, while other measurements were concerned with the production of scientific knowledge, namely research and development (R&D), not its distribution.

Machlup's calculations gave rise to a whole literature on the knowledge economy, its policies and its measurement. The first wave, starting in the 1970s, was concerned with the so-called information economy. In fact, both information and knowledge as terms were used interchangeably in the literature. Using Machlup's insights and the System of National Accounts as source for data, M. U. Porat calculated that the information economy amounted to 46% of GNP and 53% of labour income in the United States in 1967. [4] Porat's study launched a series of similar analyses conducted in several countries

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[1] The author thanks Michel Menou for comments on a preliminary draft of this paper.
[2] D. Foray (2004), *Economics of Knowledge*, Cambridge (Mass.): MIT Press.
[3] F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press.
[4] M. U. Porat (1977), *The Information Economy*, Nine volumes, Office of Telecommunication, US Department of Commerce, Washington.

and international organizations. [5] The second wave of studies on the knowledge economy started in the 1990s and still continues today. The OECD, and D. Foray as consultant to the organization, re-launched the concept of a knowledge economy, with characteristics broadly similar to those Machlup identified. [6]

This paper is concerned with explaining where Machlup's concept of the knowledge economy comes from. In fact, from the then-current literature, it can easily be seen that the term, as well as Machlup's definition, was not entirely new. Philosophy was full of reflections on knowledge, and some economists were beginning to develop an interest in the concept. Equally, Machlup's method for measuring knowledge – accounting – already existed, namely in the fields of the economics of research and the economics of education. So, where does Machlup's originality lie?

The thesis of this paper is that *The Production and Distribution of Knowledge* is a work of synthesis. First, the book is a synthesis of Machlup own work conducted prior to the publication. Second, and more importantly, the book is a synthesis of ideas from four disciplines or fields of research: philosophy (epistemology), mathematics (cybernetics), economics (information) and national accounting. Contrary to the view of some economists, this paper takes Machlup's work on knowledge seriously. R. N. Langlois, for example, has suggested that *The Production and Distribution of Knowledge* is "more a semantic exercise than an economic analysis (…), categorizing and classifying, defining and refining, organizing and labeling". [7] Given the influence the book had on science studies (although not on the economic literature) and on policy discourses, we believe this assertion biases history. As we discuss, there are several methods for quantifying knowledge, and these are in competition. Machlup's method was definitely not orthodox in mainstream economics, and Langlois' judgment precisely illustrates this fact.

[5] B. Godin (2008), *The Information Economy: The History of a Concept Through its Measurement, or How to Make Politically Relevant Indicators, 1949-2005*, Project on the History and Sociology of S&T Statistics, Montreal: INRS, Forthcoming.
[6] B. Godin (2006), The Knowledge-Based Economy: Conceptual Framework of Buzzword?, *Journal of Technology Transfer*, 31, pp. 17-30.
[7] R. N. Langlois (1985), From the Knowledge of Economics to the Economics of Knowledge: Fritz Machlup on Methodology and on the Knowledge Society, *Research in the History of Economic Thought and Methodology*, 3, pp. 225-235.

The first part of this paper discusses Machlup's construction of the concept of knowledge and the sources of this construction. It looks at the definition of knowledge as both scientific and ordinary knowledge, and both production and distribution, and its "operationalization" into four components: education, R&D, communication and information. Writings on epistemology, cybernetics and the economics of information are identified as the main intellectual inspiration for this construction. The second part analyzes Machlup's measurement of the knowledge economy based on a method of national accounting. This method is contrasted to economists' most cherished method: growth accounting. The final part identifies the message or policy issues that Machlup associated with the knowledge economy.

Machlup's Construction

Fritz Machlup (1902-1983), born in Austria, studied economics under Ludwig von Mises and Friedrich Hayek at the University of Vienna in the 1920s, and emigrated to the United States in 1933. [8] His two main areas of work were industrial organization and monetary economics, but he also had a life-long interest in the methodology of economics and the ideal-typical role of assumptions in economic theory. Machlup's work on the knowledge economy, a work of a methodological nature, grew out of five lectures he gave in 1959 and 1960. The rationale or motive Machlup offered for studying the economics of knowledge was the centrality of knowledge in society, despite the absence of theorizing in the economic literature. To Machlup, "knowledge has always played a part in economic analysis, or at least certain kinds of knowledge have (…). But to most economists and for most problems of economics the state of knowledge and its distribution in society are among the data assumed as given". [9] To Machlup, "now, the growth of technical knowledge, and the growth of productivity that may result from it, are certainly important factors in the analysis of economic growth and other economic

[8] He taught at the University of Buffalo (1935-1947), then Johns Hopkins (1947-1960), then Princeton (1960-1971). After retiring in 1971, he joined New York University until his death.
[9] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.* pp. 3-4.

problems”. [10] However, Machlup argued, there are other types of knowledge in addition to scientific knowledge. There is also knowledge of an “unproductive” type for which society allocates ample resources: schools, books, radio and television. Also, organizations rely more and more on “brain work” of various sorts: “besides the researchers, designers, and planners, quite naturally, the executives, the secretaries, and all the transmitters of knowledge (...) come into focus”. [11] To Machlup, these kinds of knowledge deserve study.

Machlup listed eleven reasons for studying the economics of knowledge, among them: [12]

- Knowledge’s increasing share of the nation’s budget.
- Knowledge’s social benefits, which exceed private benefits.
- Knowledge as strongly associated with increases in productivity and economic growth.
- Knowledge’s linkages to new information and communication technologies.
- Shifts of demand from physical labour to brain workers.
- Improving and adjusting the national-income accounting.

Armed with such a rationale, Machlup suggested a definition of knowledge that had two characteristics. First, Machlup’s definition included all kinds of knowledge, scientific and ordinary knowledge: “we may designate as knowledge anything that is known by somebody”. [13] Second, knowledge was defined as consisting of both its production and distribution: “producing knowledge will mean, in this book, not only discovering, inventing, designing and planning, but also disseminating and communicating”. [14]

Defining Knowledge

The first aspect of Machlup’s concept of knowledge was including all kinds of knowledge, not only scientific knowledge, but ordinary knowledge as well. Until then,

[10] *Ibid*. p. 5.
[11] *Ibid*. p. 7.
[12] *Ibid*. pp. 9-10.
[13] *Ibid*. p. 7.

most writings on knowledge were philosophical, and were of a positivistic nature: knowledge was "true" knowledge. [15] As a consequence, the philosophy of practical or ordinary action "intellectualized" human action. Action was defined as a matter of rationality and logic: actions start with deliberation, then intention, then decision. [16] Similarly, writings on decision making were conducted under the assumption of strict rationality (rational choice theory). [17]

In 1949, the philosopher G. Ryle criticized what he called the cultural primacy of intellectual work. [18] By this, he meant understanding the primary activity of mind as theorizing, or knowledge of true propositions or facts. Such knowledge or theorizing Ryle called "knowing that". "Both philosophers and laymen tend to treat intellectual operations as the core of mental conduct (cognition). (...) The capacity for rigorous theory that lays the superiority of men over animals, of civilized men over barbarians and even of the divine mind over human mind (...), the capacity to attain knowledge of truth was the defining property of a mind". [19]

To Ryle, there were other intellectual activities in addition to theorizing. To "knowing that", Ryle added "knowing how". Intelligence is "the ability, or inability, to do certain sorts of things", the ability to "know how to perform tasks". [20] These tasks are not preceded by intellectual theorizing. "Knowing how" is a disposition, a skill, and is a matter of competence. Acting intelligently is applying rules, without necessarily theorizing about them first. To Ryle, the error comes from the old analytical separation of mind (mental) and body (physical): doing is not itself a mental operation, so performing "intelligent" action must come from thinking.

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[14] *Ibidem*.
[15] A. J. Ayer (1956), *The Problem of Knowledge*, Harmondsworth: Penguin Books.
[16] R .J. Bernstein (1971), *Praxis and Action*, Philadelphia: University of Pennsylvania Press.
[17] S. M. Amadae (2003), *Rationalizing Capitalist Democracy: the Cold War Origins of Rational Choice Liberalism*, Chicago: University of Chicago Press.
[18] G. Ryle (1949), *The Concept of Mind*, Chicago: University of Chicago Press.
[19] *Ibid*. p. 26.
[20] *Ibid*. pp. 27-28.

Ryle was one of the philosophers who were increasingly concerned with subjective knowledge. [21] The chemist and philosopher M. Polanyi drew a similar distinction to Ryle's ten years later in *Personal Knowledge*, between what he called connoisseurship, as the art of knowing, and skills, as the art of doing. [22] In this same book, Polanyi also brought forth the idea of inarticulate intelligence, or tacit knowledge, and this vocabulary became central to the modern conception of knowledge in science studies [23] – together with concepts such as learning-by-doing: [24]

- information (data; facts) versus knowledge (useful information).
- codified versus "uncodified" knowledge (not generally available).
- tacit knowledge (individual and experiential).

Knowledge as subjective knowledge came to economics via the Austrian school of economists, [25] among them F. A. Hayek. In Hayek's hands, the concept of knowledge was used as a criticism of the assumption of perfect information in economic theory. As is well known, information is a central concept of neoclassical economic theory: people have perfect information of the markets, and firms have perfect information of the technology of the time, or production opportunities. This is the familiar assumption of economic theory concerned with rational order, coordination and equilibrium, and its modern formulation owes its existence to J. R. Hicks, P. Samuelson and G. Debreu. As Hayek put it: "If we possess all the relevant information, if we can start out from a given

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[21] At about the same time, B. Russell distinguished between what he called social and individual knowledge, the first concerned with learned knowledge, the other with experience. See: B. Russell (1948), *Human Knowledge: its Scope and Limits*, New York: Simon and Schuster. See also: A. Schutz (1962) *Collected Papers I: the Structure of Social Reality*, Dorcrecht: Kluwer; A. Schutz and T. Luickmann (1973), *The Structures of the Life-World*, Evanston: Northwestern University Press.

[22] M. Polanyi (1958), *Personal Knowledge: Towards a Post-Critical Philosophy*, Chicago: University of Chicago Press.

[23] See, for example: S. G. Winter (1987), Knowledge and Competence as Strategic Assets, in D. J. Teece (ed.), *The Competitive Challenge*, Cambridge: Ballinger, pp. 159-184.

[24] K. J. Arrow (1962), The Economic Implication of Learning-by-Doing, *Review of Economic Studies*, 29, pp. 155-173.

[25] C. Knudsen (2004), Alfred Schutz, Austrian Economists and the Knowledge Problem, *Rationality and Society*, 16 (1), pp. 45-89.

system of preferences and if we command complete knowledge of available means, the problem which remains is purely one of logic". [26]

But to Hayek, knowledge is never for the whole society given. Social knowledge is "dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is thus not merely a problem of how to allocate given resources (…). It is rather a problem of how to secure the best use of resources known to any of the members of society (…). To put it briefly, it is a problem of the utilization of knowledge not given to anyone in its totality". [27] "Any approach, such as that of mathematical economics with its simultaneous equations, which in effect starts from the assumption that people's knowledge corresponds with the objective facts of the situation, systematically leaves out what is our main task to explain". [28]

To Hayek, as to Ryle, objective or "scientific knowledge is not the sum of all knowledge". [29] There are different kinds of knowledge: unorganized, particular, individual, practical, skill, and experience. In real life, no one has perfect information, but they have the capacity and skill to find information. This knowledge has nothing to do with a pure logic of choice, but is knowledge relevant to actions and plans. This kind of knowledge, unfortunately for mathematical economists, "cannot enter into statistics": it is mostly subjective. "To what extent", thus asked Hayek, "does formal economic analysis convey any knowledge about what happens in the real world". [30] To Hayek, economic equilibrium is not an (optimal) outcome (or state), but a process (activity) – the coordination of individuals' plans and actions. In this process, individuals learn from experience and acquire knowledge about things, events and others that help them to act. In this sense, the system of prices plays the role of a signal; prices direct attention: "the whole reason for employing the price mechanism is to tell individuals that what they are

[26] F. A. Hayek (1945), The Use of Knowledge in Society, *American Economic Review*, 35 (4), pp. 519-530, p. 519.
[27] *Ibid*. 519-520.
[28] Ibid. p. 530.
[29] *Ibid*. p. 521.
[30] F. A. Hayek (1937), Economics and Knowledge, *Economica*, 4, pp. 33-54.

doing, or can do, has for some reason for which they are not responsible become less or more demanded". [31] "The price system is a mechanism for communicating information". [32]

Although perfect information, particularly information on prices, would continue defining economic orthodoxy in the 1960s (and after), more and more economists got interested in types of information, or knowledge different from strict rationality and prices, [33] and in analysis of the economics of information itself. [34] The economics of science was one field where information took center stage. From the start, the problem of science was defined in terms of decisions under uncertainty: how do you allocate resources to research, where benefits are uncertain and long-term? Researchers from RAND, [35] among them K. Arrow, [36] then came to define scientific knowledge as information, with specific characteristics that made of it a public good: indivisibility, non-appropriability, uncertainty.

As can be seen, an interest in studying information or knowledge differently was developing from various economic angles in the 1950s and early 1960s. The new developments shared a different understanding apart from strictly objective knowledge. This was also Machlup's move. In line with Ryle and Hayek, Machlup argued for

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[31] F. A. Hayek (1968) [1978], Competition as a Discovery Procedure, in *New Studies in Philosophy, Economics and the History of Ideas*, London: Routledge, pp. 179-190, p. 187.

[32] F. A. Hayek (1945), The Use of Knowledge in Society, *op. cit*. p. 526.

[33] Knowledge of others' behavior (strategic), knowledge of institutions and rules, bounded rationality.

[34] G. J. Stigler (1961), The Economics of Information, *Journal of Political Economy*, LXIX (3), pp. 213-225; K. E. Boulding (1966), The Economics of Knowledge and the Knowledge of Economics, *American Economic Review*, 56 (1-2), pp. 1-13; J. Marschak (1968), Economics of Inquiring, Communicating, Deciding, *American Economic Review*, 58 (2), pp. 1-18; J. Marschak (1974), Economic Information, Decision and Prediction, Dordrecht: Reidel; D. Lamberton (1971), *Economics of Information and Knowledge*, Harmondsworth: Penguin; K. J. Arrow (1973), *Information and Economic Behavior*, Lecture Given at the 1972 Nobel Prize Celebration, Stockholm: Federation of Swedish Industries; K.J. Arrow (1974), Limited Knowledge and Economic Analysis, *American Economic Review*, 64, pp. 1-10; K. J. Arrow (1979), The Economics of Information, in M. L. Deltouzos and J. Moses (eds.), *The Computer Age: A Twenty-Year View*, Cambridge (Mass.): MIT Press, pp. 306-317; K. J. Arrow (1984), *The Economics of Information*, Cambridge (Mass.): Harvard University Press; J. E. Stigler (1985), Information and Economic Analysis: A Perspective, *Economic Journal*, 95, pp. 21-41.

[35] D. A. Hounshell (1997), The Cold War, RAND, and the Generation of Knowledge, 1946-1962, *Historical Studies in the Physical and Biological Sciences*, 27 (2), pp. 237-267.

"subjective" knowledge. To Machlup, knowledge "must not be limited by positivistic restrictions" and need not be "true" knowledge: "knowledge need not be knowledge of certified events and tested theories; it may be knowledge of statements and pronouncements, conjectures and hypotheses, no matter what their status of verification may be". [37] To Machlup, "all knowledge regardless of the strength of belief in it or warranty for it" is knowledge. [38]

After discussing existing classifications of knowledge and their limitations, [39] Machlup identified five types of knowledge. [40] His classification or definition of knowledge served as the basis for selecting activities and measuring the contribution of knowledge to the economy:

- practical (professional, business, workers, political, households).
- intellectual.
- small-talk and pastime (entertainment and curiosity).
- spiritual.
- "unwanted" (accidentally acquired).

"Operationalizing" Knowledge

Defining knowledge as composed of all kinds of knowledge, scientific and ordinary, was the first aspect of Machlup's definition of knowledge. The second was defining knowledge as both its production and distribution. To Machlup, information is knowledge only if it is communicated and used. This theoretical insight allowed Machlup

[36] K. J. Arrow (1962), Economic Welfare and the Allocation of Resources for Invention, In National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press, pp. 609-625.
[37] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 23.
[38] *Ibid*.
[39] Basic vs. applied (difficulties in separating the two), scientific vs. historical (focusing largely on school learning), enduring vs. transitory (the latter nevertheless has great economic value), instrumental vs. intellectual vs. spiritual (no place for knowledge of transitory value).
[40] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., pp. 22-23.

to "operationalize" his concept of knowledge as being composed of four elements: education, R&D, communication and information.

According to Machlup, the largest sector of the knowledge economy is concerned with distribution, and education itself is the largest part of this "industry". To Machlup, education includes not just formal education in school, but also informal education. Eight categories or sources of education were identified: home (mothers educating children), school, training on the job (systematic and formal, excluding learning on the job), church, armed forces, television, self-education, and experience. Machlup concentrated his analysis on the first six, in which knowledge is systematic or transmitted by a teacher, but was able to measure only the first four due to statistical difficulties.

The second component of knowledge, the creation of knowledge or R&D, was what Machlup called the narrow sense of knowledge, as opposed to his wider definition, which included its distribution. To Machlup, R&D, commonly defined as the sum of basic research, applied research and development, was inappropriate. [41] In lieu of the existing classification as used by the US National Science Foundation, for example, he offered a classification based on a four-stage "model" – which culminated in innovation, a term Machlup explicitly preferred not to use:

Basic research → Inventive work → Development → Plant construction

Machlup was here taking stock of the new literature on the economics of innovation and its linear model. [42] To economists, innovation included more than R&D. Economists defined innovation as different from invention as studied by historians. Innovation was

[41] Other distinctions he discussed were: discovery vs. invention (W. C. Kneale), major vs. minor inventions (S. C. Gilfillan and W. F. Ogburn).
[42] B. Godin (2006), The Linear Model of Innovation: the Historical Construction of an Analytical Framework, Science, *Technology and Human Values*, 31 (6), pp. 1-29; B. Godin (2007), *In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Innovation*, Project on the History and Sociology of S&T Statistics, INRS: Montreal, Forthcoming.

defined as the commercialization of invention by firms. To Machlup, adhering to such an understanding was part of his analytical move away from the primacy of scientific knowledge, or intellectual work.

The third component of Machlup's "operationalization" of knowledge was media (of communication). Since all kinds of knowledge were relevant knowledge to Machlup, not only scientific knowledge but also ordinary knowledge, he considered a large range of vehicles for distribution: printing (books, periodicals, newspapers), photography and phonography, stage and cinema, broadcasting (radio and television), advertising and public relations, telephone, telegraph and postal service, and conventions.

The final component of Machlup's "operationalization" was information, itself composed of two elements: information services and information machines (technologies). Information services, the eligibility for inclusion of which "may be questioned" in a narrow concept of knowledge, [43] were: professional services (legal, engineering, accounting and auditing, and medical), finance, insurance and real estate, wholesale trade, and government. Information machines, of which he says "the recent development of the electronic-computer industry provides a story that must not be missed", [44] included signaling devices, instruments for measurement, observation and control, office information machines, and electronic computers.

Where does Machlup's idea of defining knowledge as both production and distribution come from? Certainly, production and distribution are key concepts of economics for centuries. However, the idea also derives from the mathematical theory of communication, as developed independently by C. Shannon and N. Wiener in the late 1940s. [45] In the following decades, this theory became very popular in several disciplines,

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[43] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 323.
[44] *Ibid*. p. 295.
[45] C. E. Shannon (1948), A Mathematical Theory of Communication, in *C. E. Shannon, Collected Papers*, edited by N. J. A. Sloane and A. D. Wyner, New York: IEEE Press, pp. 5-83; N. Wiener (1948), *Cybernetics: Or Control and Communication in the Animal and the Machine*, Cambridge (Mass.): MIT Press; C. E. Shannon and W. Weaver (1949), *Mathematical Theory of Communication*, Urbana: University of Illinois Press.

such as biology [46] and the social sciences. [47] Economics, [48] and the economics of information, would be no exception, [49] and neither would science studies. [50] The theory of communication defined information in terms of probability and entropy, and "the content of information as resulting from the probability of this message being chosen among a number of alternative communication channels". Schematically, the theory portrayed information as a process involving three elements: [51]

Transmitter → Message → Receiver

To Machlup, "modern communication theory has given a description of the process between and within two persons or units in a system, one the transmitter, the other the receiver of the message. The transmitter selects the message from his information store, transmits it, usually after encoding it into a signal, through a communication channel to the receiver, who, after decoding the signal, puts the message into his information store". [52] What types of communicators are involved in this process? To Machlup, communicators, or knowledge-producers as he suggested calling them, were of several types, "according to the degree to which the messages delivered to a person differ from the messages he has previously received". He identified six types of knowledge-producers:

- Transporter: delivers exactly what he has received, without changing it in the least (ex.: a messenger carrying a written communication).

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[46] L. E. Kay (2000), How a Genetic Code Became an Information System, in A. C. Hughes and H. P. Hughes (eds.), *Systems, Experts, and Computers*, Cambridge (Mass.): MIT Press, pp. 463-491.

[47] S.J. Heims (1991), *Constructing a Social Science for Postwar America: The Cybernetics Group, 1946-1953*, Cambridge (Mass.): MIT Press.

[48] P. Mirowsky (2002), *Machine Dreams: Economics Becomes a Cyborg Science*, Cambridge: Cambridge University Press.

[49] J. Marschak (1959), Remarks on the Economics of Information, in *Contributions to Scientific Research in Management*, Western Data Processing Center, Los Angeles: University of California, pp. 79-98; J. Marschak (1968), Economics of Inquiring, Communicating, Deciding, *op. cit*.

[50] E. M. Rogers and F. F. Shoemaker (1970), *Communication of Innovation: a Cross-Cultural Approach*, New York: Free Press.

[51] W. Weaver (1949), The Mathematics of Communication, *Scientific American*, 181 (1), pp. 11-15.

[52] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 31.

- Transformer: changes the form of the message received, but not its content (ex.: a stenographer).
- Processor: changes both form and content of what he has received, by routine procedures like combinations or computations (ex.: an accountant).
- Interpreter: changes form and content, but use imagination to create new form effects (ex.: a translator).
- Analyzer: uses so much judgment and intuition that the message which he communicates bears little or no resemblance to the message received.
- Original creator: adds so much of his invention genius and creative imagination that only weak and indirect connections can be found between what he has received and what he communicates.

To Machlup, knowledge covers the "entire spectrum of activities, from the transporter of knowledge up to the original creator". [53] His selection of industries for operationalizing knowledge's activities illustrates this variety. He selected thirty specific groups of industries, or activities as follows, covering the whole spectrum from creators to transporters:

Education
- In the home
- On the job
- In the church
- In the armed forces
- Elementary and secondary
- Colleges and universities
- Commercial, vocational and residential
- Federal funds
- Public libraries

R&D
- Basic research
- Applied research

Printing and Publishing
- Books and pamphlets
- Periodicals
- Newspapers
- Stationery and other office suppliers
- Commercial printing and lithography

Information machines
- Printing trades machines
- Musical instruments
- Motion picture apparatus and equipment
- Telephone and telegraph equipment
- Signaling devices
- Measuring and controlling instruments
- Typewriters
- Electronic computers
- Other office machines
- Office-machine parts

Personal services
- Legal
- Engineering and architectural
- Accounting and auditing
- Medical

Financial services

[53] *Ibid*., p. 33.

Photography and phonography
Photography
Phonography
Stage, podium and screen
Theatres and concerts
Spectator sports
Motion pictures
Radio and television
Advertising
Telecommunication media
Telephone
Telegraph
Postal service
Conventions
Check-deposit banking
Securities brokers
Insurance agents
Real estate agents
Wholesale agents
Miscellaneous business services
Government
Federal
State and local

Despite his use of communication theory, [54] Machlup did not retain the theory of communication's key term – information. As he explained later, in a book he edited on information in 1984, information in cybernetics is either a metaphor (as in the case of machine) or has nothing to do with meaning but is a statistical probability of a sign or signal being selected (case of transmission): "real information can come only from an informant. Information without an informant – without a person who tells something – is information in an only metaphoric sense". [55] Machlup preferred using the term knowledge. In fact, Machlup refused to distinguish information (events or facts) from knowledge. To Machlup, knowledge has a double meaning: "both what we know and our state of knowing it". [56] The first is knowledge as state, or result, while the second meaning is knowledge as process, or activity. From an economic point of view, the second (transmission of knowledge) is as important as the first: "Knowledge - in the sense of what is known - is not really complete until it has been transmitted to some others". [57] This was Machlup's rationale for using the term knowledge rather than information: "Information as that which is being communicated becomes identical with knowledge in the sense of that which is known". [58] Thus Machlup suggested that it is

[54] Machlup quoted Weaver at two occasions in his book.
[55] F. Machlup (1983) Semantic Quirks in Studies of Information, in F. Machlup and U. Mansfield (eds.), *The Study of Information: Interdisciplinary Messages*, New York: John Wiley, p. 657.
[56] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 13.
[57] *Ibid*. p. 14.
[58] *Ibid*. p. 15.

“more desirable to use, whenever possible, the word knowledge”, like the ordinary use of the word, where all information is knowledge. [59]

Measuring Knowledge

When Machlup published *The Production and Distribution of Knowledge*, the economic analysis of science was just beginning. [60] A “breakthrough” of the time was R. M. Solow’s paper on using the production function to estimate the role of science and technology in economic growth and productivity. [61] The production function is an equation, or econometric “model”, that links the quantity produced of a good (output) to quantities of input. There are at any given time, or so argue economists, inputs (labour, capital) available to the firm, and a large variety of techniques by which these inputs can be combined to yield the desired (maximum) output. Using the production function, Solow formalized early works on growth accounting (decomposing GDP into capital and labour), and equated the residual in his equation with technical change – although it included everything that was neither capital nor labour – as “a shorthand expression for any kind of shift in the production function”. Integrating science and technology was thus not a deliberate initiative, but it soon became a fruitful one. Solow estimated that nearly 90% of growth was due to the residual. In the following years, researchers began adding variables to the equation in order to better isolate science and technology, [62] or adjusting the input and capital factors to capture quality changes in output. [63]

According to Machlup, a mathematical exercise such as the production function was “only an abstract construction designed to characterize some quantitative relationships

[59] *Ibid*. p. 8.
[60] D. A. Hounshell (2000), The Medium is the Message, or How Context Matters: The RAND Corporation Builds an Economics of Innovation, 1946-1962, in A. C. Hughes and H. P. Hughes (eds.), Systems, Experts, and Computers, *op. cit*., pp. 255-310.
[61] R. M. Solow (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, August, pp. 312-320.
[62] E. F. Denison (1962), *The Sources of Economic Growth in the United States and the Alternatives Before Us*, Committee for Economic Development, New York; E. F. Denison (1967), *Why Growth Rates Differ*, Washington: Brookings Institution.
[63] D. W. Jorgenson and Z. Griliches (1967), The Explanation of Productivity Change, *Review of Economic Studies*, 34 (3), pp. 249-283.

which are regarded as empirically relevant". [64] What the production function demonstrated was a correlation between input and output, rather than any causality: "a most extravagant increase in input might yield no invention whatsoever, and a reduction in inventive effort might by a fluke result in the output that had in vain been sought with great expense". [65] To Machlup, there were two schools of thought: "According to the acceleration school, the more that is invented the easier it becomes to invent still more – every new invention furnishes a new idea for potential combination (…). According to the retardation school, the more that is invented, the harder it becomes to invent still more – there are limits to the improvement of technology". [66] To Machlup, the first hypothesis was "probably more plausible", but "an increase in opportunities to invent need not mean that inventions become easier to make; on the contrary, they become harder. In this case there would be a retardation of invention (…)", [67] because "it is possible for society to devote such large amounts of productive resources to the production of inventions that additional inputs will lead to less than proportional increases in output". [68]

For measuring knowledge, Machlup chose another method than econometrics and the production function, namely national accounting. National accounting goes back to the 18th Century and what was then called political arithmetic. [69] But national accounting really developed after World War II with the establishment of a standardized System of National Accounts, which allowed a national bureau of statistics to collect data on the

[64] F. Machlup (1962), The Supply of Inventors and Inventions, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*., pp. 143-169, p. 155.
[65] *Ibid*. p. 153.
[66] *Ibid*. p. 156.
[67] *Ibid*. p. 162.
[68] *Ibid*. p. 163.
[69] P. Deane (1955), The Implications of Early National Income Estimates for the Measurement of Long-Term Economic Growth in the United Kingdom, *Economic Development and Cultural Change*, 4 (1), Part I, pp. 3-38; P. Buck (1977), Seventeenth-Century Political Arithmetic: Civil Strife and Vital Statistics, *ISIS*, 68 (241), pp. 67-84; P. Buck (1982), People Who Counted: Political Arithmetic in the 18th Century, *ISIS*, 73 (266), pp. 28-45; J. E. Cookson (1983), Political Arithmetic and War in Britain, 1793-1815, *War and Society*, 1, pp. 37-60; A. M. Endres (1985), The Functions of Numerical Data in the Writings of Graunt, Petty, and Davenant, *History of Political Economy*, 17 (2), pp. 245-264; J. Mykkanen (1994), To Methodize and Regulate Them: William Petty's Governmental Science of Statistics, *History of the Human Sciences*, 7 (3), pp. 65-88; J. Hoppit (1996), Political Arithmetic in 18th Century England, *Economic History Review*, 49 (3), pp. 516-540.

production of economic goods and services in a country in a systematic way. [70] Unfortunately for Machlup, knowledge was not – and is still not – a category of the National System of Accounts.

There are, argued Machlup, "insurmountable obstacles in a statistical analysis of the knowledge industry". [71] Usually, in economic theory, "production implies that valuable input is allocated to the bringing forth of a valuable output", but with knowledge there is no physical output, and knowledge is most of the time not sold on the market. [72] The need for statistically operational concepts forced Machlup to concentrate on costs, or national income accounting. To estimate costs [73] and sales of knowledge products and services, Machlup collected numbers from diverse sources, both private and public. However, measuring costs meant that no data were available on the internal (non-marketed) production and use of knowledge, for example inside a firm: "all the people whose work consists of conferring, negotiating, planning, directing, reading, note-taking, writing, drawing, blueprinting, calculating, dictating, telephoning, card-punching, typing, multigraphing, recording, checking, and many others, are engaged in the production of knowledge". [74] Machlup thus looked at complementary data to capture the internal market for knowledge. He conducted work on occupational classes of the census, differentiating classes of white-collar workers who were knowledge-producing workers from those that were not, and computing the national income of these occupations. [75] Machlup then arrived at his famous estimate: the knowledge economy was worth $136.4 million, or 29% of GNP in 1958, had grown at a rate of 8.8% per year over the period 1947-58, and occupied people representing 26.9% of the national income:

[70] P. Studenski (1958), *The Income of Nations: Theory, Measurement, and Analysis, Past and Present*, New York: New York University Press; N. Ruggles and R. Ruggles (1970), *The Design of Economic Accounts*, National Bureau of Economic Research, New York: Columbia University Press; J. W. Kendrick (1970), The Historical Development of National-Income Accounts, *History of Political Economy*, 2 (1), pp. 284-315; A. Sauvy (1970), Histoire de la comptabilité nationale, *Économie et Statistique*, 14, pp. 19-32; C. S. Carson (1975), The History of the United States National Income and Product Accounts: the Development of an Analytical Tool, *Review of Income and Wealth*, 21 (2), pp. 153-181; F. Fourquet (1980), *Les comptes de la puissance*, Paris: Encres; A. Vanoli (2002), *Une histoire de la comptabilité nationale*, Paris: La Découverte.
[71] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 44.
[72] *Ibid*. p. 36.
[73] Machlup preferred the concept of investments in the case of education and R&D.
[74] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 41.

	$ (millions)	%
Education	60.194	44.1
R&D	10.990	8.1
Media of communication	38.369	28.1
Information machines	8.922	6.5
Information services	17.961	13.2

In conducting his accounting exercise, Machlup benefited from the experience of previous exercises conducted on education [76] and human capital, [77] and, above all, on research or R&D. The US National Science Foundation, as the producer of official statistics on science in the United States, started collecting data on R&D expenditures in the early 1950s. [78] Regular surveys were conducted on four economic sectors: government, universities, firms and non-profit organizations. Then, in 1956, the Foundation published its "first systematic effort to obtain a systematic across-the-board picture". [79] It consisted of the sum of the results of the sectoral surveys for estimating national funds for R&D. The National Science Foundation calculated that the national budget for R&D amounted to $5.4 billion in 1953.

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[75] *Ibid*. pp. 383 and 386.

[76] J. D. Wiles (1956), The Nation's Intellectual Investment, *Bulletin of the Oxford University Institute of Statistics*, 18 (3), pp. 279-290.

[77] J. R. Walsh (1935), Capital Concept Applied to Man, *Quarterly Journal of Economics*, 49 (2), pp. 255-285; J. Mincer (1958), Investment in Human Capital and Personal Income Distribution, *Journal of Political Economy*, 66 (4), pp. 281-302; T. W. Schultz (1959), Investment in Man: An Economist's View, *Social Service Review*, 33 (2), pp. 109-117; T. W. Schultz (1960), Capital Formation by Education, *Journal of Political Economy*, 68 (6), pp. 571-583; T. W. Schultz (1961), Investment in Human Capital, *American Economic Review*, 51 (1), pp. 1-17; T. W. Schultz (1961), Education and Economic Growth, in N. B. Henry (ed.), *Social Forces Influencing American Education*, Chicago: University of Chicago Press, pp. 46-88; T. W. Schultz (1962), Reflections on Investment in Man, *Journal of Political Economy*, 70 (5), pp. 1-8; G. S. Becker (1962), Investment in Human Capital: A Theoretical Analysis, *Journal of Political Economy*, 70 (5), pp. 9-4; W. L. Hansen (1963), Total and Private Rates of Return to Investment in Schooling, *Journal of Political Economy*, 71, pp. 128-140.

[78] B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

[79] NSF (1956), Expenditures for R&D in the United States: 1953, *Reviews of Data on R&D*, 1, NSF 56-28, Washington.

From the start, the data on R&D from the National Science Foundation were framed into the System of National Accounts' framework as model: surveys were conducted according to economic sectors, the classifications used corresponded to available classifications, the matrix of R&D money flows imitated the input-output tables accompanying the System of National Accounts, and a ratio R&D/GNP was constructed. To the National Science Foundation, such an alignment with the System of National Accounts was its way to relate R&D to economic output statistically: describing "the manner in which R&D expenditures enter the gross national product in order to assist in establishing a basis for valid measures of the relationships of such expenditures to aggregate economic output". [80]

Machlup made wide use of the National Science Foundation's data for his own accounting. As R. N. Nelson once stated: "the National Science Foundation has been very important in focusing the attention of economists on R&D (organized inventive activity), and the statistical series the NSF has collected and published have given social scientists something to work with". [81] The organization's numbers were one of many sources Machlup added together in calculating his estimate of the size of the knowledge economy. In fact, for most of his calculations, Machlup did not use the System of National Accounts, as Porat would for his work on the information economy. Instead he looked liberally at the literature for available numbers, like the National Science Foundation data, and conducted many different calculations (summations, mathematical projections, estimations, and computations of opportunity costs). Neither was Machlup addicted to accounting. Although he chose costs for his estimate of the knowledge economy, he discussed and suggested many other statistics. For media of communication, he looked at the number of books and periodicals, their circulation and content; for information, he collected numbers on types of technology, and use of technologies in households; on education, he recommended using numbers on attendance, years of schooling, achievement tests, number of class hours, amount of homework, and subject-

[80] NSF (1961), R&D and the GNP, *Reviews of Data on R&D*, 26, NSF 61-9, p. 1.

matter requirements; for R&D, he proposed a list of measures on input and output (see Appendix 1), and relationships or ratios between the two. [82]

Machlup was realistic about his own accounting, qualifying some of his estimates as being speculative, [83] that is, ideas of magnitude and trends based on conjecture rather than exact figures, [84] and he qualified some of his comparisons "with several grains of salt". [85] To Machlup, it was the message rather than the statistical adequacy that was important. The very last sentence of the book reads as follows: "concern about their accuracy [statistical tables] should not crowd out the message it conveys". [86]

The Message

Apart from theoretical borrowings from philosophy, mathematics, economics and national accounting, we can identify policy issues and even professional interests in Machlup's analysis at several levels First, Machlup was concerned with the challenges facing the education and research system of which he was part. Second, he was concerned, as analyst, with the new information technology "revolution".

For each of the four components "operationalizing" his definition of knowledge, Machlup identified policy issues, and this partly explains the inclusion of the components in the "operationalization". The policy issues Machlup identified were mainly economic. To begin with education, the central question discussed was productivity. Machlup distinguished productivity *in* education (or performance) [87] from productivity *of* education (or simply productivity). With regard to productivity in education, Machlup suggested compressing the curriculum to accelerate the production of well-trained

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[81] R. R. Nelson (1962), Introduction, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press, p. 4.
[82] For an in-depth discussion of Machlup on this topic, see: F. Machlup (1960), The Supply of Inventors and Inventions, *Weltwirtschaftliches Archiv*, 85, pp. 210-254.
[83] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 62.
[84] *Ibid.* p. 103.
[85] *Ibid*. p. 374.
[86] *Ibid*. p. 400.
[87] Input-output ratios.

brainpower and therefore economic growth. “We need an educational system that will significantly raise the intellectual capacity of our people. There is at present a great scarcity of brainpower in our labor force (…). Unless our labor force changes its composition so as to include a much higher share of well-trained brainpower, the economic growth of the nation will be stunted and even more serious problems of employability will arise”. [88] Concerning the productivity of education, he suggested considering (and measuring) education as an investment rather than as a cost, and as an investment not only to the individual (earnings) but also to society (culture), in line with studies on social rates of return on research. [89]

As to the second component – R&D – Machlup confessed that “this subject was his first interest in the field of knowledge production. The temptation to expand the area of study to cover the entire industry came later, and proved irresistible”. [90] To Machlup, the policy issues involving R&D were twofold. One was the decline of inventions. From the early 1950s, Machlup had studied monopolies and the role of patents in competition, [91] and particularly the role of the patent system in inducing invention. [92] Following several authors, among them J. Schmookler, [93] he calculated a decline in patenting activity after 1920. [94] He wondered whether this was due to the patent system itself, or to other factors. In the absence of empirical evidence, he suggested that “faith alone, not evidence, supports” the patent system. To Machlup, it seems “not very likely that the patent system makes much difference regarding R&D expenditures of large firms”. [95]

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[88] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 135.
[89] T. W. Shultz (1953), *The Economic Organization of Agriculture*, New York: McGraw-Hill, pp. 114-122; Z. Griliches (1958), Research Costs and Social Returns: Hybrid Corn and Related Innovation, *Journal of Political Economy*, 46, pp. 419-431.
[90] *Ibid*. p. 48.
[91] F. Machlup (1952), *The Political Economy of Monopoly: Business, Labor and Government Policies*, Baltimore: Johns Hopkins Press, pp. 280-286.
[92] F. Machlup and E. Penrose (1950), The Patent Controversy in the Nineteenth Century, *Journal of Economic History*, 1 (1), pp. 1-29; F. Machlup (1958), *An Economic Review of the Patent System*, Study no. 15, Committee on the Judiciary, 85th Congress, Second Session, Washington.
[93] J. Schmookler (1954), The Level of Inventive Activity, *Review of Economics and Statistics*, May, pp. 183-190.
[94] F. Machlup (1961), Patents and Inventive Efforts, *Science*, 133 (3463), May 12, pp. 1463-1466.
[95] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 170.

A second policy issue concerning R&D was the productivity of research, and his concern with this issue grew out of previous reflections on the allocation of resources to research activities and the inelasticity in the short-term supply of scientists and engineers. [96] To Machlup, research, particularly basic research, is an investment, not a cost. Research leads to an increase in economic output and productivity (goods and services), and society gains from investing in basic research with public funds: the social rate of return is higher than private ones, [97] and "the nation has probably no other field of investment that yields return of this order". [98] But there actually was a preference for applied research in America, claimed Machlup: "American preference for practical knowledge over theoretical, abstract knowledge is a very old story". [99] That there was a "disproportionate support of applied work" [100] was a popular thesis of the time among scientists. [101] To Machlup, there was a social cost to this: echoing V. Bush, according to whom "applied research invariably drives out pure" research, [102] Machlup argued that industry picks up potential scientists before they have completed their studies, and dries up the supply of research personnel (shortages). Furthermore, if investments in basic research remain too low (8% of total expenditures on R&D), applied research will suffer in the long run, since it depends entirely on basic research. Such was the rhetoric of the scientific community's members at the time.

These were the main policy issues Machlup discussed. Concerning the last two components of his definition – communication and information – Machlup was very brief. In fact, his policy concern was mainly with information technologies and the technological revolution. To Machlup, the important issue here was twofold. The first part was rational decision-making: the effects of information machines are "improved records, improved decision-making, and improved process controls (…) that permit

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[96] F. Machlup (1958), Can There Be Too Much Research?, *Science*, 128 (3335), November 28, pp. 1320-1325.
[97] Z. Griliches (1958), Research Costs and Social Returns: Hybrid Corn and Related Innovation, *op. cit.*
[98] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 189.
[99] *Ibid*. pp. 201-202.
[100] *Ibid*. p. 203.
[101] N. Reingold (1971), American Indifference to Basic Research: A Reappraisal, in N. Reingold, *Science: American Style*, New Brunswick and London: Rutgers University Press, 1991, pp. 54-75.
[102] V. Bush (1945) [1995], *Science: The Endless Frontier*, North Stratford (N.H.): Ayer Company Publishers, p. xxvi.

economies". [103] Machlup was here offering what would become the main line of argument for the information economy in the 1980s and after: information technologies as a source of growth and productivity. The second part was the issue of structural change and unemployment ("replacement of men by machines"). Structural change was a concern for many in the 1940s and 1950s, and the economist W. Leontief devoted numerous efforts to measuring it using input-output tables and accounting as a framework. [104] "There has been", stated Machlup, "a succession of occupations leading [the movement to a knowledge economy], first clerical, then administrative and managerial, and now professional and technical personnel (…), a continuing movement from manual to mental, and from less to more highly trained labor". [105] To Machlup, "technological progress has been such as to favor the employment of knowledge-producing workers", [106] but there was the danger of increasing unemployment among unskilled manual labour. [107] In the long run, however, "the demand for more information may partially offset the labor-replacing effect of the computer-machine". [108]

With regard to communication, the fourth component of his "operationalization" of knowledge, Machlup discussed no specific policy issue. But there was one in the background, namely the information explosion. [109] In the 1950s, the management of scientific and technical literature emerged as a concern to many scientists and universities, and increasingly to governments. According to several authors, among them science historian D. Price, scientific and technical information, as measured by counting journals and papers, was growing exponentially. Science was "near a crisis", claimed

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[103] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 321.
[104] W. Leontief (1936), Quantitative Input and Output Relations in the Economic Systems of the United States, *Review of Economic Statistics*, 18 (3), pp. 105-125; W. Leontief (ed.) (1953), *Studies in the Structure of the American Economy*, New York: Oxford University Press; W. Leontief (1986), *Input-Output Economics*, Oxford: Oxford University Press. See also: W. Leontief (1952), Machines and Man, *Scientific American*, 187, pp. 150-160; W. Leontief (1985), The Choice of Technology, *Scientific American*, 252, pp. 37-45; W. Leontief and F. Duchin (1986), *The Future Impact of Automation on Workers*, Oxford: Oxford University Press.
[105] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, pp. 396-397.
[106] *Ibid*. p. 396.
[107] *Ibid*. p. 397.
[108] *Ibid*. p. 321.
[109] B. Godin (2007), The Information Economy, *op. cit.*

Price, because of the proliferation and superabundance of literature. [110] "Some radically new technique must be evolved if publication is to continue as a useful contribution". [111] The issue gave rise to scientific and technical information policies starting from the early 1960s, as a precursor to policies on the information economy and, later, on information technology. [112]

In 1962, Machlup did not discuss the issue of information explosion. He even thought that counting the number of books was a "very misleading index of knowledge". [113] However, in the 1970s, he conducted a study on "The production and distribution of scientific and technological information", published in four volumes as *Information through the Printed World*. [114] Produced for the National Science Foundation, the study looked at books, journals, libraries, and their information services from a quantitative point of view, as had been done in *The Production and Distribution of Knowledge*: the structure of the industries, markets, sales, prices, revenues, costs, collections, circulation, evaluation, and use.

Machlup wrote on knowledge at a time when science, or scientific knowledge, was increasingly believed to be of central importance to society – and scientists benefited largely from public investments in research. Economists, according to whom "if society devotes considerable amounts of its resources to any particular activity, will want to look into this allocation and get an idea of the magnitude of the activity, its major breakdown, and its relation to other activities", [115] started measuring the new phenomenon, and were increasingly solicited by governments to demonstrate empirically the contribution of science to society – cost control on research expenditures was not yet in sight. Machlup was part of this "movement", with his own intellectual contribution.

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[110] D. D. S. Price (1956), The Exponential Curse of Science, *Discovery*, 17, pp. 240-243.
[111] D. D. S. Price (1961), *Science since Babylon*, New Haven: Yale University Press.
[112] B. Godin (2007), The Information Economy, *op. cit*.
[113] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 122.
[114] F. Machlup and K. Lesson (1978-1980), *Information through the Printed World: the Dissemination of Scholarly, Scientific, and Intellectual Knowledge*, New York: Praeger.

Conclusion

Machlup's study on the knowledge economy accomplished three tasks. It defined knowledge, measured it, and identified policy issues. The message was that knowledge was an important component of the economy, but does not completely respond to an economic logic. With *The Production and Distribution of Knowledge*, Machlup brought the concept of knowledge into science policies and science studies. His conception of knowledge was synthesized from three intellectual trends of the time: "disintellectualizing" and "subjectivizing" knowledge (ordinary knowledge), looking at knowledge as a communication process (production and distribution), and measuring its contribution to the economy (in terms of accounting).

In the early 1980s, Machlup began updating his study on the knowledge economy with a projected ten-volume series entitled *Knowledge: its Creation, Distribution, and Economic Significance*. [116] He died after finishing the third volume. By then, he was only one of many measuring the knowledge or information economy. With this new project, Machlup kept to his original method as developed in 1962: national accounting. This was a deliberate choice. In fact, there were two types of accounting measurement in the economic literature of the time. One is growth accounting. It uses econometrics, and was the cherished method among quantitative economists. With the aid of equations and statistical correlations, economists tried to measure the role of knowledge in economic growth, following Solow's footsteps. Machlup did not believe in this method. The second method is national accounting. This method was not very attractive to economists – although developed by one of them (S. Kuznets). It relied on descriptive statistics rather than formalization. Its bad reputation, and the reluctance of economists to use national accounting have a long tradition, going back to the arguments of 18th Century classical economists against political arithmetic. [117] It was such a reluctance that economist R. R.

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[115] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 7.
[116] F. Machlup (1980-84), *Knowledge: its Creation, Distribution, and Economic Significance*, Princeton: Princeton University Press.
[117] K. Johannisson (1990), Society in Numbers: the Debate over Quantification in 18th Century Political Economy, in T. Frangsmyr et al. (eds.), *The Quantifying Spirit in the Eighteenth Century*, Berkeley: University of California Press, pp. 343-361.

Nelson expressed while reviewing Machlup's book in *Science* in 1963. Nelson expressed his disappointment that Machlup had not studied the role and function of knowledge: "Machlup is concerned principally with identifying and quantifying the inputs and outputs of the knowledge-producing parts of the economy and only secondarily with analyzing the function of knowledge and information in the economic system". [118]

Machlup's Sources of Insight

Field	**Concept**	**Machlup**
Philosophy (Ryle, Polanyi)	Subjective Knowledge	KNOWLEDGE
Economics (Hayek, Arrow)	Information	
Mathematics (Sannon and Wiener)	Communication	COMMUNICATION INFORMATION
Statistics (NSF, Human Capital)	Accounting	EDUCATION R&D

Today, the measurement of knowledge is often of a third kind. Certainly, knowledge is still, most of the time, defined as Machlup suggested (creation and use) – although the term has also become a buzzword for any writing and discourse on science, technology and education. But in the official literature, knowledge is actually measured using indicators. Such measurements are to be found in publications from the OECD and the European Union, for example. Here, knowledge is measured using a series or list of

[118] R. R. Nelson (1963), Role of Knowledge in Economic Growth, *Science*, 140 (3566), May 3, pp. 473-474.

indicators gathered under the umbrella of "knowledge". [119] There is no summation (or composite value), as in accounting, but a collection of available statistics on several dimensions of knowledge, that is, science and technology, among them that on information technologies (see Appendix 2).

The methodology of indicators for measuring knowledge, information or simply science, comes partly from Machlup. We have seen how Machlup complemented his accounting exercise with discussions on various sorts of statistics, among them statistics on R&D organized into an input/output framework. In 1965, the British economist C. Freeman, as consultant to the OECD, would suggest such a collection of indicators to the organization. [120] In the 1970s, the National Science Foundation initiated such a series, entitled *Science Indicators*, which collected multiple statistics for measuring science and technology. To statistics on input, among them money devoted to R&D, the organization added statistics on output like papers, citations, patents, high technology products, etc. The rationale behind the collection of indicators was precisely that identified by Machlup as a policy issue: the "productiveness", or efficiency of the research system. [121]

So while Machlup has been influential on many aspects of the analysis of knowledge, among them on definition and measurement, still, current measurements of knowledge are restricted to scientific knowledge and information technology. Certainly, many aspects of knowledge remain non-accountable, as they were in the 1960s, but the economic orientation of policies and official statistics (economic growth and productivity) probably explains much of this orientation, to which Machlup has contributed.

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[119] B. Godin (2006), The Knowledge-Based Economy: Conceptual Framework of Buzzword?, *op. cit*.

[120] C. Freeman and A. Young (1965), *The Research and Development Effort in Western Europe, North America and the Soviet Union: An Experimental International Comparison of Research Expenditures and Manpower in 1962*, Paris: OECD.

[121] National Science Board (1973), *Science Indicators 1972*, Washington: NSF, p. iii.

Appendix 1.

Appendix

The Flow of Ideas through the Stages of Research, Invention, and Development to Application

	INPUT			OUTPUT	
Stage	Intangible	Tangible	Measurable	Intangible	Measurable
I "Basic Research" [Intended output: "Formulas"]	1. Scientific Knowledge (old stock and output from I-A) 2. Scientific problems and hunches (old stock and output from I-B, II-B and III-B)	Scientists Technical aides Clerical aides Laboratories Materials, fuel, power	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man	A. New scientific knowledge: hypotheses and theories B. New scientific problems and hunches C. New pratical problems and ideas	Research papers and memoranda; formulas ___ ___
II "Inventive Work" (Including minor improvements but excluding further development of inventions) [Intended output: "Sketches"]	1. Scientific Knowledge (old stock and output from I-A) 2. Scientific problems and hunches (old stock and output from II-A and III-A) 3. Practical problems and ideas (old stock and output from I-C, II-C, III-C and IV-A)	Scientists Non-scientist inventors Engineers Technical aides Clerical aides Laboratories Materials, fuel, power	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man	A. Raw inventions: technological recipes a. Patented inventions b. Patentable inventions, not patended but published c. Patentable inventions, neither patented nor published d. Non-patentable inventions, published e. Non-patentable inventions, not published f. Minor improvements B. New scientific problems and hunches C. New pratical problems and ideas	a. Patent applications and patents b. Technological papers and memoranda c. ___ d. Papers and memoranda e. ___ f. ___ ___ ___
III "Development Work" [Intended output: "Blueprints and Specifications"]	1. Scientific Knowledge (old stock and output from I-A) 2. Technology (old stock and output from III-A) 3. Practical problems and ideas (old stock and output from I-C, II-C, III-C and IV-A) 4. Raw inventions and improvements (old stock and output from II-A)	Scientists Engineers Technical aides Clerical aides Laboratories Materials, fuel, power Pilot plants	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man Investment	A. Developed inventions: blueprints, specifications, samples B. New scientific problems and hunches C. New pratical problems and ideas	Blueprints and specifications ___ ___
IV "New-type Plant Construction" [Intended output: "New-type plant"]	1. Developed inventions (output from III-A) 2. Business acumen and market forecasts 3. Financial resources 4. Enterprise (venturing)	Entrepreneurs Managers Financiers and bankers Builders and contractors Engineers Building materials Machines and tools	$ investment in new-type plant	A. New pratical problems and ideas	New-type plant producing a. novel products b. better products c. cheaper products

Source: F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 180-181.

Appendix 2.

Indicators on the Knowledge-Based Economy

A. Creation and Diffusion of Knowledge

Investments in knowledge
Domestic R&D expenditure
R&D financing and performance
Business R&D
R&D in selected ICT industries and ICT patents
Business R&D by size classes of firms
Collaborative efforts between business and the public sector
R&D performed by the higher education and government sectors
Public funding of biotechnology R&D and biotechnology patents
Environmental R&D in the government budget
Health-related R&D
Basic research
Defence R&D in government budgets
Tax treatment of R&D
Venture capital
Human resources
Human resources in science and technology
Researchers
International mobility of human capital
International mobility of students
Innovation expenditure and output
Patent applications
Patent families
Scientific publications

B. Information Economy

Investment in information and communication technologies (ICT)
Information and communication technology (ICT) expenditures
Occupations and skills in the information economy
Infrastructure for the information economy
Internet infrastructure
Internet use and hours spent on-line
Access to and use of the Internet by households and individuals
Internet access by enterprise size and industry
Internet and electronic commerce transactions
Price of Internet access and use
Size and growth of the ICT sector
Contribution of the ICT sector to employment growth
Contribution of the ICT sector to international trade
Cross-border mergers, acquisitions and alliances in the ICT sector

C. Global Integration of Economic Activity

International trade
Exposure to international trade competition by industry
Foreign direct investment flows
Cross-border mergers and acquisitions
Activity of foreign affiliates in manufacturing
Activity of foreign affiliates in services
Internationalization of industrial R&D
International strategic alliances between firms
Cross-border ownership of inventions
International co-operation in science and technology
Technology balance of payments

D. Economic Structure and Productivity

Differences in income and productivity
Income and productivity levels
Recent changes in productivity growth
Labour productivity by industry
Technology and knowledge-intensive industries
Structure of OECD economies
International trade by technology intensity
International trade in high and medium-high technology industries
Comparative advantage by technology intensity

Source: OECD (2001), *STI Scoreboard: Towards a Knowledge-Based Economy*, Paris: OECD.