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Science legitimacy and the postmodern condition of knowledge

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Abstract

We start by showing how science is as much a personal as a social endeavour, carefully driven between convictions and scepticism, depending on strictly defined criteria that are made possible through a conjunction of social norms intimately connected to epistemological principles. If the sociological contexts play an important role, we must recognize that science compensates their influence with the experimental gathering of evidences. However knowledge always requires a link to tradition, believe and authority, i.e., tacit knowledge and a fiduciary framework.

Objectivity can also be supported by science's success to describe and transform reality, within a renewed process that continuously expands what we know and can transform. This attests the power of science that meanwhile was separated from the ethical dimension required to all kind of knowledge appliance, thus redirecting us to the sociological contexts of science.

We then refer to how science's sociological structures consequently changed when the dimension, cost and importance of science for economic progress was such that responsibility for it was taken from the hands of scientists. The *age of competition for scarce resources* marks the end of pure intellectual competition in which science's progress was conditioned mainly by individual creativity. That's why sociological factors regain nowadays a much more important role to play in science dynamics.

The paper concludes by presenting how a new sociologically framework of scientific knowledge is emerging: the "fourth age of research" driven by international collaborations between elite research groups, strongly guided for markets, and once again science's autonomy is at stake.

Keywords: Science; Objectivity; Epistemology; Philosophy; Postmodernity

Introduction

Let us begin by reflecting a little upon science, or rather, upon the human construction of scientific knowledge. Even in the case of research into the material and impersonal world, the scientific enterprise is an activity carried out by individuals. Scientific knowledge is personal knowledge and necessarily involves value judgments and personal preconceptions, though the practice of it is

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undertaken within a community that is seeking after an "objective truth" (Polanyi, 1962). To be more explicit, it satisfies certain general principles, such as the need to be grounded in observation and experimentation, the capacity to explain and predict and its aspirations to universality and objectivity. Of course, these are abstract impersonal principles that offer no guidance as to the ethical value or utility of knowledge, nor do they shed light upon the reasons for why scientists quest after knowledge or the means they use to achieve it.

In their search for knowledge, scientists are faced with at least two vicious circles. The first is hermeneutic: we have to believe in a (pre-existing) order in order to be able to understand and we have to understand in order to believe. The other is epistemological: knowledge is controlled by the nature of the object and the nature of the object is revealed to us through the knowledge we have of it. Thus, there is a certain precariousness about scientific knowledge and to construct it we have to navigate carefully, though boldly, between credulity and scepticism, basing all our judgments upon strictly defined criteria (Polkinghorne, 1994, 32). This navigation between Scylla and Charybdis is made possible by a tacit conjunction of social norms that are intimately connected to the epistemological principles used by academics (Ziman, 1996, 751).

The conditions of objectivity in science concern both the object and the subject. Personal experience is unique and unrepeatable. It is the impersonal experiment that is repeatable, because it is relatively invulnerable to small variations of context and these are the optimum conditions for the object. In order to ensure the epistemic primacy of that object, the greatest possible neutrality towards it is required on the part of the experimenting subject. This manifests itself as the Mertonian4 sociological norm of disinterestedness: scientists arrive at the results of their research and communicate them and their claims in an impartial manner, as if they have no personal (material or psychological) interest in acceptance by the community. Compliance with this norm requires a conscious effort on the part of scientists; it also emphasizes the importance of observation and experimentation.

[4] In The Social Structure of Science (1942), Robert Merton presented a set of general norms, which tacitly rule the scientific practices, like communalism, universalism, disinterestedness, originality and scepticism. In literature, this set of norms is frequently designated by the acronym CUDOS. Although these norms are idealized standards and are being questioned by sociologists of science, they still provide our conceptual framework for discussion about the changes that are taking place in academic research and scientific enterprise. Like Kalleberg (2007, 138), we assume that "his work was not only historically important, but is also essential today". Even if we recognize Merton`s analysis can be criticized for its positivist conception of science and lacks theoretical resources to overcome conceptual issues from cultural and social sciences.

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The norm of communalism5, according to which science is perceived as a collective enterprise, means that the results of all research have to be published as early as possible. Researchers are therefore under a great deal of pressure to publish their articles as contributions (or gifts) to knowledge, since scientific knowledge is "public knowledge". The principle of universalism means that all competent researchers may openly participate, irrespective of sex, race, religion, nationality or any other affiliation6. While this norm of meritocracy may in practice be imperfect, it nonetheless insists that scientific claims be sufficiently general to be applied to any cultural context7.

The requirement of originality is an important intellectual force in science, since a scientist can only get credit for the original results of research. There must therefore be a certain freedom of choice regarding subjects to be researched and creativity and novelty are assumed to represent a source of progress in knowledge. It is this that leads to the recognition of scientists, both by peers and by society at large.

The precept of scepticism means that all research contributions are subjected to scrutiny and critical appreciation by other researchers. Academic practices, such as peer review and scientific debate aiming at scientific impartiality are based upon this norm, without resulting in systematic scepticism or social relativism.

All these social norms or philosophical principles are so profoundly enmeshed that they represent complementary facets of an ethos of individualism, whose epistemological, social and psychological components are inseparable (without, however, meaning that all scientific knowledge is relative or a mere construction to serve social interests). As Merton emphasizes, "in terms of that ethos, the social stability of science can be ensured only if adequate defences are set up against changes imposed from outside the scientific fraternity itself"(1973, 259). We can say, like Ziman (1994, 180), that "underlying the academic ethos is a non-contractual but well-established social process

[5] Merton uses the term "communism", to mean that "the substantive findings of science are a product of social collaboration and are assigned to the community. They constitute a common heritage in which the equity of the individual producer is severely limited (Merton, 1973, 273). (Where does the above quote end? End quotation marks are missing)

[6] This prescription is not only moral but functional to improve the scientific production, as we must recognize.

[7] As institutional imperative, universalism finds expression in these two kinds of requirements. The first one finds expression in the canon that "truth claims, whatever their source, are to be subjected to pre-established impersonal criteria, consonant with observation and with previously confirmed knowledge (Merton, 1973, 270). Science is assumed to be a "certified knowledge" and as such empirically confirmed and logical consistent. The norm of universalism is as "social" as "technical", concerned with the epistemic and methodological condition of truth claims and with the imperative that "the acceptance or rejection of claims entering the lists of science is not to depend on the personal or social attributes of their protagonist" (Merton, 1973, 270).

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whereby the scientific community receives contributions and provides recognition in exchange for those it values".

Common to all of these views is the idea that standards or norms are the source of science's success and authority. The characterization of scientific knowledge as dependent on rigorous testing of hypotheses gives credibility to science.8 For positivists, the key is that theories can be no more or less than the logical representation of data (e.g., Carnap, 1952). However, in the 70s, sociological criticism emerged against this representation and discourse fostering an ongoing debate about the methods of science, as well as its epistemic validity.

1. Is Science a Social Construct?

In the 70s and the 80s, a group of scholars settled in Edinburgh developed the designated *strong programme* [9] of sociology of scientific knowledge (Bloor, 1971; Shapin, 1975; McKenzie, 1981; Barnes & Bloor, 1982). The sociology of scientific knowledge (SSK) explores systematic relationships between thought and society in order to examine how human beings, as a society, construct, interpret and view "reality," less to determine the exact "nature of scientific knowledge"[10] in itself, but to understand how knowledge is socially created and, particularly, how our everyday and often unquestioned knowledge is achieved[11].

A central assumption of the sociology of SSK is that *the social organization* of a particular society affects the form knowledge will take in that society[12]. Every individual, including scientists, possesses socially situated knowledge, because one's social location affects how we think and what we think about. Neo-Marxist currents have once more taken up the old issue of social relativism to currently offer a postmodern vision of "science as a social construct", in which the evidence

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[8] As Truran emphasizes, the differences between modern science and pre-scientific inquiry concerns "rigor and organization, especially the documentation of theories and the experiments used to test them, and the establishment of institutions for discussion, critique and review of scientific ideas and development" (Truran, 2013, 12).

[9] Bloor (1991, 5) poses four tenets for sociological inquiry: its explanations must be causal, concerned with the conditions which bring beliefs or states of knowledge; they must be impartial concerning the truth or falsity of what is being explained; truth and falsity require symmetric explanations, that is, both must be explained by the same kind of causes; and finally, the inquiry must be reflexive, i.e., its principles must be applicable recursively to its results.

[10] SSK moves towards a non-foundational epistemology influenced by post-positivist ideas from Quine and Wittgenstein. About sociological influences in the strong programme, see David Kaiser (1998).

[11] As we can easily recognize, the strong programme connects to a large number of tendencies and problems in general philosophy, including logical and ontological questions regarding the nature and determinants of knowledge. The sociology of knowledge also takes a very attentive look at the behaviour of communities of experts, those that promote the representation of "reality" and "truth" in society. How do they produce their forms of knowledge? What institutions legitimate this knowledge? How is legitimacy sustained among non-experts? The analysis of these problems reveals the roots of their epistemological positions against a Parsonian functionalist sociology of norms, Mertonian sociology of science and above all against what Barnes and Bloor call a "rationalist ex ante philosophy of science" (Tyfield, 2008, 63).

[12] For a comparison between a realist-rationalist cluster and socio-historical cluster, cf. Noretta Koertge (1998, 4-7).

provided by systematic experimentation has little part to play.[13] This view of science derives from case studies into the origin and choice of theories, which involved the observation of scientists in their working environment (discussions between colleagues, interviews and analyses of laboratory notebooks) and studies of scientific debates. The Science & Technology Studies (STS) trend takes a variety of anti-essentialist positions with respect to science and technology, and tends to reject many of the elements of the common discourse of science (v.g., Price, 1977; Cutliffe, 2000).

According to this perspective, scientific knowledge is a composite of epistemological and sociological principles, on the basis of which experimenters question reality and try to convince other scientists of the value and plausibility of their explanations. However, the sociological component is difficult to sustain in light of evidence from different cultural environments and the changing interests of new generations produce a historical filter that increases, rather than reduces, objectivity. Indeed, if science (or more precisely, scientific knowledge) is truly a "social construct" in the strongest sense of the term, it would have local rather than universal validity: the laws that permit aeroplanes to fly would not permit them to fly in Africa or Asia or over any ocean, nor would a medicine developed in the United States be effective in Europe. Science is not something trumped up by intellectuals, nor is physical reality a mere puppet in the hands of different scientific theories and the changing opinions of scientists; on the contrary, physical reality intrinsically resists these ideas.

Scientists construct their theories on the basis of limited empirical data, which are often imperfect, have been selected according to a particular theory and are marked with particular jargon. The limited nature of the data has a logical implication: a finite body of empirical information cannot guarantee that the relationship between the data and a single theory that is logically inferred from it is itself unique. This has never worried scientists much, but some philosophers have been tormented by this epistemological weakness. The Edinburgh school of sociology, in its "strong programme", claims that it has identified this missing epistemological link in science, which shows that science is a cultural construct in which empirical evidence plays an insignificant role in the construction of theories (Gottfried & Wilson, 1977, 545).[14]

Philosophers are susceptible to this type of concern because they accept that a multiplicity of "good theories" may exist, all compatible with the limited experimental data, yet which may not all be

[13] According to some sociologists, science is a certain sort of activity distinguishable from other human activities by characteristics such as serious attempts at falsification, or a "loose and heterogeneous collection of more or less successful investigative practices" (Dupré, 1990, 69).

[14] As Tyfield (2008, 62) states, "finitism must now be acknowledged as a (or perhaps even the) central element of the model of Science & Technology studies (STS) associated with the Edinburgh School."

easily discovered by scientists; consequently, inferences about which of the explanations are the best are only valid for hypotheses that are historically confronted. However, history and scientific practice over four centuries have shown that these theories, when they are not unique, are limited in number and it should be recognized as an empirical fact that deductive inference works perfectly satisfactorily, since scientists have often been able to find the best explanation and thus offer a plausible account of physical reality. Indeed, it is ironic that sociologists of science recognize the important role played by case studies in the collection of empirical evidence, while despising the experimental evidence gathered by scientists. Both play an important role in the construction of their respective theories.

In his work, *Constructing Quarks: A Sociological History of Particle Physics* (1984), Pickering claims that at the cutting edge of research, scientists do not resolve their disagreements by means of better experiments, most advanced theories or most lucid thoughts. However, what some sociologists are observing are the first, still erratic efforts of some scientists to create plausible knowledge, as if trying to get out of a swamp by tugging at their shoelaces. The behaviour that Pickering records is no different from how scientists react when confronted with conflicting theories, or when a paradigm is overturned (Formosinho, 1994). When they are first constructing a theory, scientists tend to grab on to any experimental data available; however, as they gradually gain confidence in the theory – because of psychological inclination, or personal or institutional interest – they gradually lose the sense of the value of their own empirical data in the construction of the theory.

A theory has to be freed as much as possible from its sociological setting so that it can objectively confront its rivals. Kuhn (1962) attributes this role to scientific *crisis,* when conflicting paradigms shake *theoretical principles.* However, it may happen, in the present historical context that a scientist opts for a particular theory because it affords him a certain cognitive satisfaction. Afterwards, when questioned about the reasons for this choice, he may invoke all sorts of different criteria that come to mind, with internal contradictions. Many scientists reveal this kind of lack of explanatory coherence, which may result from inadequate training in overcoming epistemic difficulties, psychological inclination, or a lack of high ethical standards in the face of vested interests. Sometimes they try to "save the theory" rather than "save the phenomena". It is this kind of behaviour that results in the deformed view put forward by sociologists of science. The conclusions of these sociologists of science are betrayed by their own methodologies. Therefore, we must take account of scientific criticism and sociological criticism in order to avoid compliance with the benign neglect some demonstrate in accepting strong relativistic tendencies. As David L. Hull (1998) claims, regardless of the way in which one construes science, it can still be studied

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scientifically and one task of those of us who study science might well be to discern the regularities that characterize it. Too often the sociologists who study science tend to employ methodological practices that they would condemn as inadequate in the work of those scientists whom they study[15]. Nonetheless, sociological criticism has been useful for understanding science as the result of a historical construction from intersubjectivity – such as "the sharing of purpose and focus between individuals that involves emotional, social and cognitive exchanges" (Rogoff, 1990, p.9) – towards objectivity. As others have emphasized, "the attempt at overcoming epistemological foundationalism from the standpoint of a kind of hermeneutic philosophy of science does not imply a farewell to the defence of science's cognitive specificity" (Ginev, 2001, 33). Furthermore, we aim to commit this defence in terms of hermeneutic criticism of naive scientism, such as what can be found in Polanyi's writings.

2. A New Approach to Knowledge: The *Tacit* Dimension

In his 1960 address to the World Student Christian Federation assembly in Strasbourg, France, Michael Polanyi began the presentation of his theory of knowing by giving the example of a distinguished psychiatrist who showed his students a rare type of fit (Polanyi, 1957). Later, the students discussed the case and tried to decide whether the fit was an epileptic or hystero-epileptic seizure. The question was resolved and an important lesson taught when the psychiatrist told his students that this case was a true epileptic seizure, but that he could not tell them how he recognized it. Instead, they would have to learn to be able to do this themselves through continued experience (Gelwick, 1991). This example illustrates that there is nonverbal knowledge of impossible oral transmission. Such knowledge can only be learned, more slowly, through experience and continued working with more qualified teachers and masters.

In the preface of his collection of essays, *The Logic of Liberty* (1951), Polanyi notes that the book represents his consistently renewed efforts to clarify the position of liberty in response to a number of questions raised by our troubled period of history. This purpose, however, required a better foundation for supporting his beliefs. The theory of "tacit knowing" articulated in his Gifford Lectures (later published as *Personal Knowledge* (1958/1962)) represents the heart of Polanyi's accomplishments as a philosopher. In fact, confronted with the heritage of Enlightenment rationalism and what has come to be postmodern relativism, Polanyi's theory of knowledge neither succumbs to objectivism cultivated by modern thinking, nor does it retreat into the temptation of

[15] As Hull (1998, 212) emphasizes: "Testing the sorts of claims that scientists make is difficult enough. Testing the sorts of meta-level claims made by those of us who study science is even more difficult. Even so, we must try."

postmodern scepticism. In his desire to renew tradition, the author does not deny the important gains of modern technoscience; however, he wants to recognize the indispensable role of belief in knowledge. As Polanyi (1958, 62, 49) explains, "the exact sciences are a set of formulae which have a bearing on experience. Science is operated by the skill of the scientist and it is through the exercise of his skill that he shapes his scientific knowledge". For the author, knowledge is acquired by apprenticeship and practice; the learning of rules is the primary manner by which skilful performance is acquired, but it is not enough. Rules are maxims, which can serve as a guide only if they can be integrated into the practical knowledge of the performer; however, they cannot replace this knowledge. In a certain sense, practical knowledge precedes the knowledge of rules, for one must possess a degree of practical knowledge in order to properly apply the rules. Mitchell (2006, 64) claims that this emphasis on practical knowledge directly contradicts the modern prejudice in favour of the explicitness of rules, because if knowing is an art and if the learning of an art requires dwelling in the practices of a master, then it follows that there must exist a tradition by which an art is transmitted. Then knowledge always requires a link to tradition or authority and this fiduciary component of knowing extends to basic levels of culture and even language[16]. In this sense, all knowledge is "either tacit or rooted in tacit knowledge"[17], which requires a quote of belief and submission to authority[18].

For Polanyi, the whole universe of human ideas must be understood by dwelling within the framework of our cultural heritage, which means that tradition plays an indispensable role in the knowledge we acquire. We do not possess a virgin mind; we must acknowledge that we all are embedded in various ways – in our languages, histories, personal abilities and cultures. The linguistic tradition constitutes the framework through which the world is viewed and consequently establishes the parameters of thought. The author writes in a very expressive manner: "We must now recognize belief once more as the source of all knowledge. Tacit assent and intellectual passions, the sharing of an idiom and of a culture heritage, as well as the affiliation to like-minded community: such are the impulses which shape our vision of the nature of the things on which we rely for our mastery of things. No intelligence, however critical or original, can operate outside such

[16] As Polanyi writes: "I cannot speak except from inside a language" (Polanyi, 1958/1962, 253).

[17] Polanyi identifies four aspects of tacit knowing: functional, phenomenal, semantic and ontological (see Mitchell, 2006, 74-76).

[18] We can say that each generation incorporates a tradition, but this incorporation implies necessarily on a reinterpretation. As Mitchell (2006, 68) states, "each generation appropriates a tradition, but the appropriation necessarily entails interpretation. Interpretation, in turn, is necessarily conducted in light of the concerns, biases and circumstances of the particular generation appropriating the tradition. In addition, each person who participates in a tradition contributes to the further development of the tradition."

a fiduciary framework" (Polanyi, 1958/1962, 266)[19]. In his epistemological perspective, linguistic and cultural affinities as fiduciary elements of knowledge acquisition have undoubtedly played a role in science that has been ignored by the positivism committed to an absolute *objectivism*. Objectivism seeks to remove the human knower from the knowing process; as Polanyi explains (1958/1962, 16**),**

[M]odern man has set up as the ideal of knowledge the conception of natural science as a set of statements which is "objective", in the sense that its substance is entirely determined by observation, even while its presentation may be shaped by convention. This conception, stemming from a craving rooted in the very depths of our culture, would be shattered if the intuition of rationality in nature had to be acknowledged as a justifiable and indeed essential part of scientific theory. That is why scientific theory is represented as a mere economical description of facts; or as embodying a conventional policy for drawing empirical inferences; or as a working hypothesis, suited to man's practical convenience – interpretations that all deliberately overlook the rational core of science.

If this is the case, the crucial point for the scientist is not based on the number of events presented by a given entity, but rather in the nature of surprise that these events matter. In particular, expressions of beauty, harmony and intellectual consistency are indicative of contact with reality[20], which also contains a psychological component. The primary sense of *theoria* is simply "a looking at, a viewing, a beholding, an observing" without any necessary implication of "disengaged perspective" at all. The Greeks also used the expression *theorias eineken*, meaning "for the purpose of seeing the world" and this is exactly what a theory, in its less limited sense, actually is: something which we use for the purpose of seeing or making sense of the world. We are situated in a particular time and culture and it is from there that we have received our judgments and personal knowledge. This knowledge is relative to time and place, but our belief and desire is that it will have a universal and timeless validity. There is thus an attempt at a universal product of our contact with a reality that is external. Thus, in science and notably in the experimental sciences, scientific work is directed toward the object, and the scientist's contact with reality is made with universal intent. As

[19] Polanyi refused to discard or diminish the value of modern rationalism, but he sought to restore awareness of the role of the knower in the act of knowing. Because the foundations of knowing run deep on the mental structure of the knower, all knowledge, including scientific knowledge, is personal, not detached from the tacit convictions of someone. In contrast to Polanyi, Merton lacks a micro-sociological understanding of scientists as reasoners moving in a culture (Kalleberg, 2007, 138).

[20] Polanyi's realism depends on his belief that an external reality exists and that it is knowable. However, for him, the ideal of objectivist knowledge, detached from the knower, is an illusion20. Influenced by the findings of Gestalt psychology, the chemist regards knowing "as an active comprehension of the things known", meaning "the personal participation of the knower in all acts of understanding" (Polanyi, 1958/1962, Preface, VII).

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Polanyi writes (1958/1962, 17):

We shall find Personal Knowledge manifested in the appreciation of probability and of order in the exact sciences, and see it at work even more extensively in the way the descriptive sciences rely on skills and connoisseurship. At all these points the act of knowing includes an appraisal; and this personal coefficient, which shapes all factual knowledge, bridges in doing so the disjunction between subjectivity and objectivity. It implies the claim that man can transcend his own subjectivity by striving passionately to fulfil his personal obligations to universal standards.

In this sense, we may distinguish between the personal in us, which actively enters into our commitments, and our subjective states, in which we merely endure our feelings, and the conception of *personal knowledge*, which is neither subjective nor objective. In so far as the personal submits to requirements acknowledged by itself as independent of itself, it is not subjective; but in so far as it is an action guided by individual passions, it is not objective either. It transcends the disjunction between subjective and objective. As Jha (2002, 29) explains: "Personal knowledge is not subjective, it is objective in the sense that it establishes contact with reality" in "anticipating an indeterminate range of yet unknown true implications". As Polanyi emphasises, personal knowledge is "a responsible act claiming universal validity" (1958/1962, Preface, VII). Personal knowledge is an intellectual commitment, a "fiduciary act", which is inherently hazardous, as one's affirmation may be fallible. Fallibility is a characteristic of objective knowledge. Therefore, in Polanyi's epistemology, it is the link to externality that saves personal knowledge from subjectivity and in his redefined conception of knowledge, personal and objective components are linked. Furthermore, if the purpose of Polanyi's *Personal Knowledge*, subtitled *Towards a Post-Critical Philosophy,* is "to reequip men with the faculties which centuries of critical thought have taught them to distrust" (Polanyi, 1958/1962, 381**),** it means the recognition that in the practice of science, those who do research are passionately involved and intellectual emotions have a guiding role in scientific discovery[21].

For a discovery to have scientific value as Polanyi defines it, it must be fruitful and be able to produce new discoveries in the future; this requires openness on behalf of the scientist to a new vision of reality, like an active knower participating in all live knowledge. Moreover, just as the heuristic passion (cognitive aspect) motivated the scientist to propose his solution in an original

[21] As he writes: "Inventive efforts can never fully account for their success; but the story of man's evolution testifies to the creative power that goes beyond that which we can account for in ourselves. We exercise some of it in the simplest act of acquiring knowledge and holding it to be true. For doing so, we strive for intellectual control over things outside, in spite of our manifest incapacity to justify this hope" (Polanyi, 1964). "Science and man's place in the universe", in Harry Woolf (ed.). Science as a cultural force. Baltimore: J. Hopkins Press, 75-76 .

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framework, the persuasive passion must motivate him to persuade others (conative aspect) to incorporate his innovative solution. Competition to impose a new theory sometimes requires a conceptual reform of the premises, while the persuasive passion functions within the the scientific community controversies, similarly as heuristic passion functions at the individual level. As Jha (2002, 236), emphasizes,

[O]ne should remember that Polanyi's aim was to describe a strategy for inquiry, one that to him seemed more in keeping with the strategies of working scientists than the descriptions promoted by the logical positivists, or even by the "standard" line including Russel. Polanyi wanted to introduce a way to validate the discovery of the new, the unique act. That meant he had to open up the strategy for inquiry to the historic dimension and a teleological account of the progress of reason.

In fact, the influence of the Hungarian Chemist writings largely overcomes the initial aim, because as he recognizes "my reconsideration of scientific knowledge leads to a wide range of questions outside science" (Polanyi, 1958/1962**,** vii). However, for the purpose of our discussion in this article, his most significant contribution concerns the tacit dimension of all knowledge, including scientific knowledge. Against positivist heritage, he intended to build a post-critical philosophy that denies the absolute "objectivist" perspective in science and reintegrates the knower inside his cultural framework. With a more optimist perspective, Polanyi's view is a good counterpoint to sociological criticism and gives us a new understanding of the epistemological condition of scientific knowledge.

3. The Success of Science

Despite the criticisms addressed at scientific knowledge, we must agree that science is a very successful activity, from an epistemological and practical point of view. As Diéguez-Lucena emphasizes: "Given the physical and biological limits of human beings, it is surprising indeed that we have such a powerful tool to modify reality. Moreover, other forms of knowledge have not achieved comparable results and therefore the reasons as to why this is the case invite scrutiny" (Diéguez-Lucena, 2006, 393-394). In order to do this, we must ask how scientists can gain profound intellectual satisfaction from the conquest of a certain kind of knowledge that appears to us as fundamental and unique. We have said that scientists construct scientific knowledge, but this "construction" has to be counterbalanced with a sense of "discovery". Scientists do not merely examine nature critically; they also congratulate themselves on their discoveries and are irrepressibly thrilled by the notion that a world exists independent of themselves and permits them to explore it.

We should explain that there is something "transcendental" about science's attempts to understand the universe, which gives a certain intellectual satisfaction with the sense of harmony provided, that transcends the mere scientific explanation of phenomena, causes and predictions, though always passing through the former (Laudan, 1981)[22]. This is the consequence of many lines of argument converging on a common conclusion and is derived from a presupposition that had been expressed in the Middle Ages by the principle *adaequatio mentis et rei* (congruence between the mind and the way things are)[23].

Given these fundamental flaws, how can we explain the success of final results? Modern science in Western societies has its roots in professional practices that go back to the Middle Ages, when the acquisition of knowledge was cultivated as a kind of initiation rite and where ethics, as well as knowledge, was tested. Access to knowledge and its progress was expected to be accompanied by a certain ethical development, which was evaluated by the master, since knowledge on its own could be both a dangerous as well as valuable tool. Indeed, all these men of knowledge were subject to ethical norms internal to the knowledge-generating system.

With the Enlightenment of the 18th century, however, this perspective on the value of knowledge was profoundly altered. Knowledge was no longer considered dangerous; on the contrary, it began to be perceived as a good thing, which brings happiness and which should therefore be extended to as many people as possible. As man is essentially a social animal (since only within society can the destiny of mankind truly be fulfilled), the State, as holder of the legislative power that regulates the project of social living, is involved in the definition of ethical rules external to knowledge itself. Commitment to the love of truth, as both an intellectual and a moral pursuit, implies an active participation in a society that accepts the cultural obligation of regulating itself by such standards.

These internal ethical ideals point towards objectivity, impersonality and the internationalism of science; the external sociological constraints are subjective, interpersonal and national. Undoubtedly, there is a tension here that will affect the pace of scientific progress, though not the final result of that advance. If we strip each theory of its sociological wrappings and do away with historical time, we find ourselves in a situation where alternative theories are confronted under the same conditions, equivalent to the "multiple working hypothesis" or "strong inference" methods.

[22] Even if we accept some criticism to "convergent realism", as Laudan (1981) states, this does not deny all realistic positions.

[23] Believers would say that we are made in the image and likeness of God, which reflects our feeling that there must be some kind of interaction between scientific and religious understanding, a relationship of mutual support. The unity of knowledge and the unity of God are intimately connected. For these reasons, J. Polkinghorne, the Cambridge physicist and Fellow of the Royal Society who was ordained as a priest in the Anglican church in 1982, claims "an atheist is not stupid, he simply explains less" (Polkinghorne 1994, 70).

According to this, with the performance of crucial experiments to successively eliminate the hypotheses simultaneously confronted, logical inference guarantees, objectively, the best explanation. Of course, a great deal of ground may have had to be covered before the best solution is found and the path to it may be long and difficult, with occasional relapses. Nevertheless, the historical path already contains the best solution in a seminal way. Thus, we should not take as an absolute value the dynamics of scientific practice, as sociologists of science tend to. It should be counterbalanced by a historical perspective that takes account of its successes and failures and its capacity to inspire new questions and new practices. According to this, the predictive character of science is tacitly present in the spirit of researchers and when realized over time, wins over new supporters and even public opinion. Nevertheless, sociological studies are important for an understanding of the history of scientific knowledge, as well as for the alterations in the sociological structures of science[24].

4. Alterations in the Sociological Structures of Science

In 1963, sociologist of science, Della de Solla Price (1963/1986), showed that scientific activity as expressed by the number of scientific journals available had grown exponentially over the previous 300 years (from 1665 to the given date). The number of articles published doubled in 10-15 years at an annual growth rate of between 5% and 7%. Modern science was clearly *in expansion* and had been from the 17th century. This pace of growth is understandable, because the resolution of any scientific problem raises a host of new questions. In addition, a successful scientist does not work alone, but supervises a number of disciples; for the most brilliant among them, new academic and research positions are created. In this way, the talents of a particular generation open up the way for the next.[25] Price also draws attention to the fact that the way of doing scientific research has changed since the beginning of the 20th century, subsequently modifying the sociological structures

[24] We can take note of Koertge's (1998, 25-26.) commentary: "Whatever its faults, Science Studies is not "a house built on sand." It is better conceived as a colony strung out on a difficult, but strategically important, seashore. Some of the buildings – gross and gaudy in self-advertisement – stand on pathetically slender foundations; they hardly need a tsunami to wash them away, the merest ripple will do. Others are a curious mixture of craftsman-like work and jerry-building, often with a folly or a vast, unscoured stable attached. A few buildings, more modest, sneered at or ignored by the most ambitious architects, are constructed to last. Perhaps if this image is accepted, we can begin to see that we should neither announce utopia nor call for the bulldozers. What is needed is slum clearance and urban renewal, a project in which historians, philosophers, sociologists, and scientists all should all be invited to join".

[25] With the annual pace of growth at between 5% and 7%, Price, in 1963, was already warning that the cost of research (which was approximately 1% of Gross Domestic Product that year) would increase to 5% of the GDP in 2000 and reach 20% in 2030. As this is clearly unsustainable, Price predicted a decline in the pace of growth. Regarding costs of experimental and technological research and development (R&D), stabilization would occur around the mid-1970s at 2% to 3% of the GDP in advanced countries like the United States, Japan, the United Kingdom and Germany (cf. J. Ziman, 1994, 10).

of science. This was particularly evident in the last quarter of the 20th century, when the dimension, cost and importance of science for economic progress were such that responsibility for it could no longer be left in the hands of scientists (Lyotard, 1984). Today, in the more advanced countries, science is in a *dynamic steady state* and the practice of it is conditioned by the availability of funding, the creation and filling of academic and research posts in institutions, and access to the pages of respected journals (*era of competition for scarce resources*). This contrasts the *age of pure intellectual competition*, in which the progress of science was conditioned only by the limits of the imagination and creativity of scientists. It is to this phase that most of our historical and scientific narratives refer.

As it is the most advanced scientific communities that determine the standards of science at any given moment, the transition from "science in expansion" to "science in a dynamic steady state" naturally has global implications. These implications are not only economic, but also sociological, psychological and philosophical. In future, readers of the history of science will have to take account of external factors to a much greater extent than they do now and will inevitably find that sociological factors have a much more important role to play in the pace of scientific progress and subversion of scientific paradigms. The historical route leading to objectivity will be much more difficult to trace in each branch of knowledge and it will take longer, because at the very foundations of the scientific construct, the subject is more bound to the physical object of his study, and has more vested interests of an economic, professional and psychological nature. Consequently, sociological studies of science-as-practice will take on an increased value in the future. Indeed, the sociological scenario that Kuhn allowed us to glimpse in *The Structure of Scientific Revolutions* (1962) (i.e., the radical change brought about in the nature and efficiency of research in a particular scientific domain by the raising of a network of credible concepts, or paradigm and the revolutions unleashed by the subversion of the dominant paradigm in the choice of a new theory) will be in future an open door.

Science in a dynamic steady state is characterized by another cluster of social norms, some of which are opposed to the "pure" science cultivated in universities. This science is proprietary, local, authoritarian, commissioned and specialist in nature (Ziman, 1994). The concept of the *intellectual property* of generated knowledge gives the right not only to peer recognition but also to remuneration and it is this that lies at the heart of any scientific career in industry, in a state-funded laboratory and presently in the universities where this scientific system flourishes. The most lucrative knowledge generally has a *local* rather than universal character; it is not accessible to all, since confidentiality may be a source of profit (commercial secrecy, patents, licences, agreements for the transfer of technology). It follows an *authoritarian* management model as opposed to the liberalism of traditional academic science. The research is optimally conducted as a sequence of pre-planned and *commissioned* projects rather than through a personal freedom to choose an area of research, decide what scientific problems to tackle in this area and set about tackling them in one's own way. It aims to train *specialists* that are experts in certain areas and skills, though not so hyper-specialized that they will rapidly become obsolete. The universities, on the other hand, have not traditionally shown much corporate interest in the research undertaken by their professors; they have selected the best people to occupy academic posts and then allowed them the freedom to undertake whatever research they wished. Most academics only managed to satisfy the norms of originality and success in scientific debate by concentrating for years on a highly specialized and narrow area.

Science in a dynamic steady state is not limited by a lack of ideas, creativity or good scientific projects, nor by the lack of human or technical resources to carry them out; it is society that is reluctant to finance all those good projects. This is because science today is not a low-cost activity *(sponsored subsidized activity).* Societies, through their governments, allow the "science market" to select the topics of research, which it then *purchases* by means of financing agencies, government departments, industries, commercial companies, international agencies, etc. This is because science and technology have become the most powerful engines of economic and social development in today's world, with effects in the fields of economics, politics and culture. Consequently, governments establish *priorities* for the research to be financed, based not only upon scientific factors, but also upon political, commercial, demographic, social and fiscal concerns. They also seek to optimize the returns on these financial investments in order to ensure that sufficient *added value* is generated as regards the national priorities.

It is clear that the unpredictable outcome of science is now subordinated to pragmatic criteria. Scientific research has always been oriented towards some purpose, but this is not the same thing as having secure knowledge of the results to be achieved. A scientific project cannot be approached in the same way as the construction of a building or machine. The safest criterion for success is for the project to be registered by the person responsible for it. Indeed, the very notion of the *scientific project* is a new concept in the construction of science, deriving from science in a dynamic steady state. In fact, to compensate for the unpredictable outcome of scientific research, the distinction between pure and applied science is becoming blurred; this is because practical applications may require basic research for a better understanding of the phenomena, mechanisms and concepts required for interconnection with other domains with short-or-medium-term objectives. It is a new

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model of *strategic research* with long-term goals that aims to achieve a more generic form of knowledge enabling the resolution of many of the problems that concern society.

At present, this new science is organized in a way that brings it closer to the kind of research carried out in industry or by state-funded laboratories. It is more directed and there is more strategic manoeuvring and competition in the management of it. It is also characterized by increased responsibility concerning *accountability* and the administration of financial resources (which must comply with the planned objectives, overheads, etc.); the sharing of expensive equipment and the costs of maintaining and operating them; the sharing of other infrastructures (electronic and mechanical); the establishment of critical standards and stimulation of centres of excellence and competence; legal formalization in the form of contracts, etc. In addition, there is a very stringent selection process that concentrates almost all available resources upon the most able, the so-called "Matthew effect" ("to everyone that has will more be given; but from he who has not, even what he has will be taken away")[26]. Hardly any of these factors were part of traditional scientific practice.

Public opinion has also altered in terms of the value and purpose of science and governments have adjusted their policies to suit the perspectives of the citizen-taxpayer. The public is more impatient with science; it wants spectacular results, fast and in many diverse fields. This inevitably puts enormous social pressure on scientific communities. For this reason, research projects are assessed for their societal relevance, environmental impact and technological, economic and cultural implications, and all this will naturally affect the anticipated results.

In the past, science was labour intensive and research costs were largely measured by the amount of time that professors and researchers spent engaged in this activity; increase in costs was therefore controlled by salaries and by the number of academic posts available. Now, in this new system, science is capital intensive. Costs mostly reflect the expenses of purchasing, maintaining and operating scientific equipment (including the specialized technicians and researchers needed to work it), while account must also be taken of depreciation, since new equipment rapidly becomes obsolete, lowering the quality of the research produced with it. In this scenario, universities find it increasingly difficult to make funds available for financing research that may arise out of some unexpected but promising discovery. Consequently, science is becoming an industry in which success is rare and elusive and where profits rarely go to the initial investors.

[26] "The Matthew Effect", dubbed by Merton, applies to research groups as well as to individual scientists, as Zyman claims (Zyman, 1994, 65).

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5. Towards a New Type of Scientific Knowledge

According to Ziman (1994), a "cultural revolution" is taking place in academic science as it concerns employment conditions, choice of subjects to research, criteria for success, funding, etc. This new science is so different (sociologically and epistemologically) from what came before that it produces an entirely different kind of knowledge. The norm of communalism has been reinforced with the new forms of electronic communication that are now available, but much of the knowledge generated will not be public property. Ease of communication, like the transnational character of many projects, favours the norm of universalism, though not necessarily in the philosophical sense; for the researcher does not seek knowledge for knowledge's sake, but rather aims to solve specific problems. This may require an amalgamation of empirical data, theories, computational and simulation means, and methodologies taken from the spectrum of "experimental and technological research and development", without undue concern for inconsistencies (and therefore not necessarily complying with the criteria of "good science"). However, the knowledge generated will have the advantage of being able to plug many of the gaps left in the "map of scientific knowledge" created by science in expansion and of associating itself unreservedly to basic science and technological development[27].

The whole policy of establishing scientific priorities means that the choice of research topic is no longer an individual matter. Topics will be chosen collectively, rather than individually, in accordance with the philosophical tendencies of postmodernism, in which knowledge is conceived in a more holistic way[28] and where the community has a part to play (Reber, 2007). The new post-academic science will possibly amalgamate the elitism of the peer review system and other kinds of quality control imported from industry; this will mean that a much broader range of criteria will be used to judge excellence than what was consensually agreed by academics; aspects such as competence in management and an entrepreneurial spirit are also likely to become important.

Evaluation by specialists (peer review) has constituted one of the pillars of modern science. It involves the prior examination of scientific claims that are sent to scientific journals, ensuring that they are validated by the scientific community. More recently, the same system has been used in the selection of research projects for funding. In assessing the contributions submitted for publication by other colleagues, the editors and referees of scientific journals act in accordance with the

[27] As Lyotard explains, the technological transformation changes the condition of knowledge. He writes, "knowledge is and will be produced in order to be sold, it is and will be consumed in order to be valorised in a new production: in both cases the goal is exchange (Lyotard, 1984, 4).

[28] Hyper-specialisation will be prevented by the insecurity of academic and research posts in science, since no researcher will have the time for profound, mature, exhaustive studies of a particular subject. Consequently, scientific knowledge can be much less fragmented in future.

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dominant scientific consensus. Nevertheless, they should also judge the quality of the claims presented objectively, respecting the intellectual independence of the authors. In fact, the history and practice of science shows that there is a delicate balance between the value of consensual scientific information and the right to dissidence, which of course is a considerable source of innovation and progress[29].

Goodstein also offers an important warning about the "erosion of principles" (Lawrence & Locke, 1977, 757) that is very threatening to science and associated with other forms of dishonest behaviour, such as plagiarism and fabrication and falsification of results – essentially forms of "scientific fraud" resulting from ambition and impatience[30]. The second "warning" is different, yet both reveal that the impartiality of science could be at risk in the solution of certain social conflicts.

John Ziman recognizes that the new science will certainly not involve the total abandonment of all traditional principles and norms in a bid to follow postmodern trends. However, we will see the extreme universal rationalism of the philosophy of the sciences gradually giving way to a greater and more localized pragmatism. Philosophers and sociologists of science agree that the notion of the scientist as someone in search of the truth, aspiring to almost absolute objectivity, is incompatible with social reality. All of us try to promote our own personal and institutional interests in our scientific work. However, the great virtue of academic science has been its emphasis upon the norm of disinterestedness, which it has sustained throughout history. Ziman sees a serious risk in the loss of scientific objectivity resulting from this new post-academic way of doing science. It is not that what passes as scientific knowledge at a particular moment does not depend upon how the research is organized in this composite of philosophy and sociology in which science

[29] Given the epistemological and sociological importance of the peer review system for the construction of credible scientific knowledge, a series of studies have appeared on the reliability, impartiality and validity of the judgments and decisions provided by peers in relation to articles submitted for publication.29 At a conference sponsored by the New York Academy of Sciences, David Goodstein gave the following opinion about the state of the refereeing system: "Throughout most of its recent history, science was constrained only by the limits and creativity of its participants. In the past couple of decades that state of affairs has changed dramatically. Science is now constrained primarily by the number of research posts, and the amount of research funds available. What had previously always been a purely intellectual competition has now become an intense competition for scarce resources. This change, which is permanent and irreversible is likely to have an undesirable effect in the long run on ethical behaviour among scientists. Instances of scientific fraud are almost sure to become more common, but so are other forms of scientific behaviour. For example, the institution of peer review is now in critical danger. […] Peer review is quite a good way to identify valid science. It was wonderfully well suited to an earlier era, when progress in science was limited only by the number of good ideas available. Peer review is not at all well suited, however, to adjudicate an intense competition for scarce resources such as research funds or pages in prestigious journals. The reason is obvious enough. The referee, who is always among the few genuine experts in the field, has an obvious conflict of interest. It would take impossibly high ethical standards for referees to fail to use their privileged anonymity to their own advantage, but at the same time more and more referees have their critical ethical standards eroded by receiving unfair reviews when they are authors. Thus the whole system of peer review is in peril" (D. Goodstein, 1996, 36). About research on bias in the peer review system, see also C.J. Lee, C. R. Sugimoto, G. Zhang & B. Cronin (2013).

[30] About this question see ESF/ALLEA (2011). The European Code of Conduct for Research Integrity. Strasbourg, ESF/Amsterdam.

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exists; rather, it is that, in the academic tradition, scientific knowledge is not constructed to satisfy certain social interests (such as economics, efficiency, profit, safety and well-being). Scientific objectivity has been an internally-regulated cultural norm that has managed to survive after history has rid knowledge of the temporal markers resulting from psychological or cultural factors. From this perspective, we might urge society not to kill the goose that lays the golden eggs.

Conclusions

A final word about the possible consequences of postmodern science for scientific vocations. The dominant way of conducting postmodern science is in fact "normal science" (in Kuhn's sense), which bears the safest fruit and most pleases the funding agencies, which follows methodologies that are tacitly accepted and which systematically expand to more and more systems. It is a laborious, persistent, meticulous and efficient task, ultimately a safe investment for a technological society.

Research has progressed through three ages: the individual, the institutional and the national. Today, we are entering a "fourth age of research"[31] driven by international collaborations between elite research groups. This will challenge the ability of nations to conserve their scientific wealth either as intellectual property or as research talent. Tensions are growing between the knowledge a country needs to remain competitive, the assets it can exclusively secure and the collaborative parts of the research base. Institutions that do not form international collaborations risk progressive disenfranchisement and countries that do not nurture their talent will lose out entirely. There is a strong contrast between the two extremes of the research ages. In the first age it was common to have theories or methodologies with a "name", such as "Hammond postulate" and "pasteurization". Presently, at the other extreme, anonymous teams carry out research, as is the case regarding the human genome. Science massively undertaken, as made possible by the new kind of organisation and by digital technologies, will undermine the idea of individual originality in scientific creativity, as some fear[32]. However, the human factor, with its creativity and originality has been the driving force of scientific development. Scientific production is downplaying the role of the scientist and takes away his romantic aura. This may be a possible cause to be considered in the crisis of the scientific vocations that we are witnessing amongst young people in developed countries.

[31] Jonathan Adams (2013). "The fourth age of research", Nature, 497, 557-560.
[32] See, for example, D. Keith Simonton (2013). Scientific genius is extinct. Nature, 493, 602.

References

Adams, J. (2013). The fourth age of research. *Nature*, 497, 557-560.

Bloor, .(1976/1991). *Knowledge and Social Imagery.* Chicago: University of Chicago Press.

Borgman, C. L. & Furner, J. (2002). Scholarly communication and bibliometrics. *Annual Review of Information Science and Technology,* 36, 3-72.

Carnap, R. (1928/1952). *The logical structure of the world.* Berkeley: University of California Press.

Diéguez-Lucena, A. (2006). Why does Laudan's confutation of convergent realism fail? *Journal for General Philosophy of Science*, 37, 393-403.

Dupré, J. (1990). Scientific Pluralism and the Plurality of the Sciences: Comments on David Hull's Science as a Process. *Philosophical Studies*, 60, 61-76.

Formosinho, S. (1998). "O sistema de avaliação por pares numa ciência em regime estacionário" *Revista Portuguesa de Filosofia 54,* pp. 551-533.

Formosinho, S. J. (1994). *O Imprimatur da Ciência,* Coimbra: Coimbra Editora.

Gelwick, R. 1991. Michael Polanyi and the Philosophy of Medicine. *Tradition & Discovery*, 18 (3), 21-29.

Goodstein, D. (1966). Conduct and Misconduct in Science. *Annals of the New York Academy of Sciences*, Vol. 775, pp.31-38.

Gottfried, K. & Wilson, K.G. (1977). Science as a cultural construct. *Nature*, 386, pp. 545-547.

Gusdorf, G. (1960). *Introduction aux sciences humaines*. Paris: Societé des Belles Lettres.

Harbers, J. A. (2005). Science in Context: The Paradoxes of Universalism and Liberalism. *Science, Technology, & Human Values*, 30 (4), p. 575-582.

Hess, D. J. (1997). *Science studies: An advanced introduction*. New York: New York University Press.

Hull, D. L. (1998). Studying the study of science scientifically. *Perspectives on Science*, 6 (3), 209-231.

Kaiser, D. (1998). A Manheim for all seasons: Bloor**,** Merton and the roots of the sociology of scientific knowledge. *Science in Context*, 11, 51-87.

Kalleberg, R. (2007). A reconstruction of the ethos of science. *Journal of Classical Sociology*, 7 (2), 137-160.

Koertge, N. (1998). A House Built on Sand: Exposing Postmodernist Myths About Science. Accessed at www.oxfordscholarship.com.(2012), pp. 4-7.

Kostoff, R. N., *Research Programme Peer Review. Principles, Practices, Protocols*. Accessed at www.dtic.mil/dtic/kostoff/index.html.

Kuhn, T.S. (1972). *La structure des révolutions scientifiques*. Paris: Flammarion.

Lane, J. (2010). Let's make science metrics more scientific. *Nature*, 464 (7288), 488-489.

Laudan, L. (1981). A confutation of convergent realism. *Philosophy of Science,* 48 (1), (March, 81), pp. 19-49.

Lawrence, P.A., Locke, M. (1997). A Man for our Season. *Nature*, 386, pp.757-758.

Lee, C., Sugimoto, C. R., Zhang, G. & Cronin, B. (2013). Advances in information science. Bias in Peer Review. *Journal of the American Society for Information Science and Technology,* 64 (1), 2-17.

Livingstone, D. N. (2003). *Putting Science in Its Place. Geographies of Scientific Knowledge*. Chicago: University Chicago Press.

Lyotard, J.-:F. (1984). *The postmodern condition: A report on knowledge*. Minniapolis: Universityof Minnesota Press.

Merton, R. (1942). *On social structure and science*. Chicago: University of Chicago Press.

Merton, R. (1973). *The sociology of science*. Chicago: University Chicago Press.

Mitchell, M. T. (2006). *Michael Polanyi. The art of knowing*. Delaware: ISI Books.

Murphy, N. (1990). *Theology in the age of scientific reasoning*. New York: Cornell University Press.

Pickering, A. (1984). *Constructing quarks: A sociological history of particle physics*. Chicago: University Chicago Press.

Polanyi, M. (1962). *Personal knowledge*. London: Routledge & Kegan Paul.

Polanyi, M. (1957). Scientific outlook: Its sickness and cure. *Science*, 125 (March, 1957), 480-504.

Polkinghorne, J. 1994. *Science and Christian belief. Theological reflections of a bottom-up thinker*. New York: Cambridge University Press.

Price, D. J. de S. (1962). The exponential curve of science. In B. Barber and W. Hirsch (Eds.). *The sociology of science* (pp. 516–524). New York: Free Press of Glencoe.

Price, D. J. de S. (1963/1986). *Little Science, big Science and beyond*. New York: Columbia University Press.

Price, D. J. de S. (1964). The science of science. In M. Goldsmith and A. Mackay. *The science of science* (pp. 195–208). London: Souvenir Press.

Price, D. J. de S. (1965). Networks of scientific papers. *Science,* 149 (July 30), 510-515.

Reber, B. (2007). Entre participation et déliberation: Le débat public et ses analyses sont-ils hybrides du point de vue des théories politiques? *Klesis - Revue Philosophique: Philosophie et Sociologie*, Novembre 2007, 46-78.

Rogoff, B. (1990). *Apprenticeship in thinking: cognitive development in social context*. New York: Oxford University Press.

Simonton, D. K. (2013). Scientific genius is extinct. *Nature*, 493, 602.

Sismondo. S.(2010). *An introduction to Science and Technology Studies*. Oxford: Blackwell.

Truran, P. (2013). *Practical Applications of the Philosophy of Science. Thinking about Research*. Springer.

Tyfield, D. (2008). The impossibility of finitism: From SSK to ESK? *Erasmus Journal for Philosophy and Economics,* 1(1), 61-86.

Ziman, J. (1994). *Prometheus Bound. Science in a dynamic steady state*. New York: Cambridge University Press.

Ziman, J. (1997). Is Science losing its objectivity? *Nature*, 382, pp. 751-754.