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An introduction to the methods of inquiry in social sciences

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Abstract. The purpose of this paper is an introduction to methods for conducting inquiries in social sciences. A method of inquiry is an organized and systematic scientific approaches used by scholars for controlled investigations and experiments to efficiently solve theoretical and practical problems, generating discoveries and/or science advances. The paper here presents, briefly, the development of models of inquiry in the philosophy of science. After that, it introduces general methods of inquiry (deduction, induction, abduction and hypothetical-deductive approaches) and specific models of scientific inquiry in social sciences, such as multiple working hypotheses. In general, modern scientific research is multifaceted and requires different approaches for generating new concepts, new hypothesis and theories. Different methods of inquiry directed to solve problems in science can be complementary approaches that foster knowledge creation within and between research fields.
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1. Introduction

To understand science today, it is important to understand its methods of inquiry. Such models indicate how the future of scientific fields can be investigated and developed. Methods of scientific inquiry generally aim to obtain knowledge in the form of testable explanations that scientists can use to predict the results of future phenomena in nature and society (Popper, 1959). In particular, main elements of the methods of inquiry in a hypothetic deductive view are: a) observation and accurate measures of the subject of scientific inquiry; b) hypothetical explanations of the subject of inquiry; c) controlled experiment for testing the hypotheses; d) prediction[i]. Next sections, will trace the development of methods of inquiry based on scientific thinking of rationalism and empiricism, the first two major (and opposed) philosophies of science. Subsequently, a synthesis of these conflicting positions by Kant is discussed. After that, it will be traced the development of the major contemporary theories of methods of scientific inquiry: the speculative metaphysical, the positivistic, and the pragmatic (cf. Kaplan, 2009; West Churchman & Ackoff, 1950).

2. Development of the methods of scientific inquiry in the philosophy of science

2.1. Rationalism: The role of reason in science

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The school of rationalism argues that the development of reason is a basic faculty in the method of inquiry. In this approach, the Greek mathematicians had the purpose to systematize the general properties of space (i.e., geometry).

Reason was a faculty that had two fundamental features: it provides information concerning the essences of things, and it shows how to go from these essences to other characteristics of the world. Reason provides "clear and distinct" ideas, and guides to the conclusions from such ideas. The history of science and philosophy seems to show that it is no easy matter to identify the clear and distinct ideas. Leibniz attempted to overcome this difficulty by making analytic statements the beginning point of rational inquiry that cannot be denied without violating the Law of Contradiction. A problem in this approach is to connect pure formal defining to reality marked a turning point in man's thoughts on the correct process of scientific inquiry. Some contemporary scholars have attempted to use rational methods of inquiry in some scientific fields, but the modern rational method does not always provide truth. However, speculation and the clear use of reason are essentially the only methods at scholar's disposal in certain areas, such as religion, morality, and metaphysics (West Churchman & Ackoff, 1950).

2.2. Empiricism: The role of observation in science

The priority of reason was questioned and attacked by the empiricism that replaced reason by sensation as the source of all knowledge. Locke made the first comprehensive and systematic attempt to do this. Starting from simple ideas, and with the aid of the mental operations of compounding, relating, and abstracting, he sought to show how other facts (ideas) could be derived. He also tried to show how knowledge of general propositions should be derived by the process of comparing ideas. This approach by Locke was seriously challenged by the later philosophers who accepted his general program.

Berkeley and Hume showed that many ideas which appeared simple to Locke, were actually not so, and consequently they raised the problem of the adequacy of intuition or introspection as a criterion of simplicity. Locke's notion of a mental faculty of abstraction was refuted by Berkeley, who claimed that the mind can only perform generalizations, not abstractions, whereas Hume discards the faculty of generalization. Berkeley eliminates Locke's material substance, and bases all reality in mental substance. Reid and Hume show that not even the existence of a mental substance can be proved on empirical grounds. Hume also demonstrated our inability to assert any causal connections with certainty. Hence, knowledge is replaced by belief: the empirical analysis can only show with certainly our impressions.

2.3. A synthesis of reason and observation by Kant

Kant shows that both sensory observation and general understanding are essential for meaningful experience. It is true that there is something given in sensation (the sensuous intuition), but in addition to the sensuous intuition, Kant argues that both space and time are a priori forms of experience, which are necessary to individuate objects. In this approach, the mind must bring to its experience a principle of regularity. That is, the natural world is well ordered because this is the manner in which the mind makes understandable its sensuous intuitions.

2.4. Modern rationalism: The speculative method

Rationalism since Kant has turned from the rigorous method of deductive science. The newer rationalism shares with the old the belief that the mind can intuitively grasp truth; but for the newer rationalism, truth comes only at the end of the process, and very tentatively. Rational or metaphysical truth, in short, is derived by a process in which the generalizations come out of rich experience, but are not themselves mere mechanical inductions or deductions, but creative acts of the mind. For Hegel, the process was dialectical, proceeding from conflicts and working up by successive syntheses to some higher and richer stage. For Bergson, the process is intuitive. For Hall, it is imaginative insight. Finally, the modern rationalist claims that his method is in some sense basic to all others, and that other methods must always make metaphysical, or ethical assumptions that can only be justified by rational insight, intuition, faith, and the like.

2.5. The positivistic method

The development of the contemporary analysis of scientific method, called "logical positivism", is due to Hume with an attack on speculative metaphysics, which became the cornerstone of Comte's positive philosophy. Comte attempted to demonstrate that metaphysical thinking represented an intermediate historical stage through which man passed on his way to the full maturity of positive or scientific thought. Further, he constructed a hierarchy of sciences based on the temporal order and logical simplicity in the appearance of the special scientific disciplines. This notion of a hierarchy appears in new guise in logical positivism, as the theory of physicalism. In this approach, Mill attempted to show how by designing experience, causal connections could be established on purely empirical grounds. Mill, in effect, defined the problem of "inductive logic". Finally, Mach and Pearson conceived of law as an economic measure, a way of summarizing past experiences and of indicating expectations. Laws were not taken as irrefutable, exact, or as representing necessary connections in nature. They were merely taken as provisional cataloguing instruments.

2.6. The method of logical positivism

Logical positivism is a new empiricism, which unlike its predecessor, uses logical rather than psychological analyses as an instrument for the study of scientific method. It takes the understanding of language in terms of its form (syntax), content (semantics), and uses (pragmatics) to be basic to an understanding of methodological problems. It attempts to show how language construction can take place from a basic set of elements and rules. Such a language can be considered quite apart from any factual meaning. Meanings are fundamentally assigned by means of linguistic rules referring ultimately to protocol statements, which are more or less directly verified in experience. Explanation and prediction can then be given precise definitions as aspects of scientific method.

2.7. Modern synthesis: The pragmatic method

Science, in the pragmatic approach, is conceived, not in terms of what it actually does, but in terms of its aims. In the pattern of inquiry (due to Dewey), the emphasis is on the resolution of an indeterminate situation into a determinate one. The idea is that facts and concepts are instruments for certain types of action, and have no meaning apart from this context.

In order to consider the meaning of science in a more precise sense, pragmatism introduces the distinction between goals (which are presumably attainable objectives) and ideals (which are unattainable but approachable within any limits). The ideal which defines science is that of finding perfect means for any end in any situation. In so far as activity furthers man in his struggle for this ideal, it is scientific. A classification of sub-ideals represents steps in the pattern of science's progress that must be approached as science itself progresses.

Finally, pragmatism's attitude toward metaphysics and positivism is that they represent partial (and often fruitful) methods, none of which are final in themselves.

3. General models of inquiry

Considering the philosophies of science discussed above, models of scientific inquiry can be classical, pragmatic and logical empiricism approaches[ii]:

* The classical model of scientific inquiry derives from Aristotle, who

distinguished the forms of approximate and exact reasoning. A common distinction in science is between logical paths of induction and deduction. The etymology is from the Latin verb *ducere*, to draw on or along, to lead, and with the Latin propensity for prefixes. With the prefixes *in* and *de*, meaning 'in' and 'from,' respectively, both words may have many meanings. Simply, *to induce* could mean 'to lead or draw into, to infer, to persuade,' and *induction* is 'to lead to the conclusion'. *To deduce* could mean 'to lead from, to draw from' and *deduction* is 'to draw a conclusion from'. Both terms define systems of logic with the purpose of solving problems.

Deductive methodof inquiry is based on deduction: "inference by reasoning from generals to particulars," or "the process of deducing from something known or assumed". Deductive reasoning, also deductive logic, is the process of reasoning from one or more statements (premises) to reach a logically certain conclusion. Put otherwise, deductive reasoning goes in the same direction as that of the conditionals, and links premises with conclusions. If all premises are true, the terms are clear, and the rules of deductive logic are followed, then the conclusion reached is necessarily true. Deductive reasoning (top-down logic) contrasts with inductive reasoning (bottom-up logic).

Inductive model of inquiry starts by doing experiments and then derives theories from the data. This process collects data and then move to theoretical implications. Scholars are involved in a continuous loop of data collection and theory formation. Problem solving in scientific fields leads to a diversity of induction: formation of hypotheses (HPs), the need to test HPs supports the study design and controlled experimental activity: experiments, in turn, can generate consequential problems to be solved, which lead to new hypotheses and further science advances (e.g., in medicine the study of mutant cancers; cf., Coccia, 2016). Induction is riskier than deduction because it can lead to conclusions that may be uncertain. Overall, then, while the conclusion of a deductive argument is certain, the truth of the conclusion of an inductive argument may be probable, based upon the evidence given. Inductive reasoning can be a derivation of general principles from specific observations, though some sources disagree with this usage.

* Pragmatic model by Charles Sanders Peirce (1992) characterized inquiry a 'struggle' to replace doubt with 'settled belief'. The method of science is an experimental method, and the application of the pragmatist maxim[iii] reveals how hypotheses can be subject to experimental test. Dewey's conception of inquiry, found in his *Logic: the Theory of Inquiry* is to understand a problem through describing its elements and identifying their relations. Identifying a concrete question that we need to answer is a sign that we are already making progress: 'the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole' (Deway, 1938, pp.104-105). As Smith (1978, p. 98) has put it: 'Peirce aimed at "fixing" belief, whereas Dewey aimed at "fixing" the situation.' Peirce calls his pragmatism "the logic of abduction".

Abduction by Peirce is based on simple visualization of phenomena. In fact, many visual stimuli are impoverished or ambiguous, people are adept at imposing order on them, creating hypotheses to explain what has been observed. Hence, abductive reasoning (also called abduction, abductive inference, or retroduction) is a form of logical inference which starts with an observation then seeks to find the simplest and most likely explanation. In abductive reasoning, unlike deductive reasoning, the premises do not guarantee the conclusion. Abductive reasoning is an inference to the best explanation, although not all uses of the terms abduction and inference to the best explanation are exactly equivalent.

* Logical empiricism is based on a set of axioms in formal deductive systems. Theories are confirmed by deducing their effects from axioms and checking to see whether the predictions hold; this model of inquiry is called hypothetico-deductive because it uses the hypotheses to make predictions, rather than the derivation of

laws from observations, similarly to earlier empiricism (Hempel, 1965). Put otherwise, scholars with hypothetico-deductive method of inquiry state hypotheses and then do experiments to test them. In most scientific fields, the hypothetico-deductive method of scientific inquiry by Popper is the dominant model of inquiry. The approach by Popper (1959) was hypothetic deductive, however he saw the critical role of prediction to be the attempt to falsify theories, not to confirm them (cf., Thagard, 1993, p.192ff). For instance, in psychology and other social sciences, scholars state a hypothesis underpinned in a theoretical framework, then describe the materials and experimental methods, results achieved and finally discuss how experimental results bear on the initial hypothesis for possible predictions. This approach can generate distortion of the process of inquiry because it may be possible to form a sharp hypothesis and then test it with empirical evidence. The general hypothetico-deductive scheme can be synthetized in figure 1.

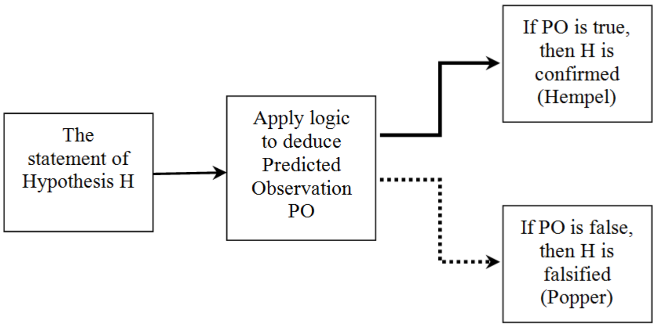

Figure 1. *Hypothetico-deductive scheme. Adapted from Thagard (1993, p.192).*

Hanson (1958) criticized this model of inquiry because theory and observation were much more intertwined. Scientific realism argues that science is not restricted to observable facts but knowledge can be achieved of what is not observable.

* Finally, analogy has a vital value in the evolution of science because the solution of problems in one scientific field—source domain — can be used for solving and explaining problems in another scientific field -target domain (Oppenheimer, 1955).

4. Specific methods of inquiry in social sciences

In the general background of the models of inquiry just mentioned, some specific methods in social sciences are as follows[iv].

4.1. Game theory

Among the social and human sciences a method of inquiry is the game theory. A "game" is any activity with the structure of a contest, in which what one player decides to do, simultaneously or not simultaneously, depends on what it expects to be done by the other players. The specific content of the actions involved is irrelevant; all that matters is the payoff to the players associated with each possible combination of moves by the two sides. In this way utility theory also enters into the analysis. The game model thus serves for a wide variety of decision-making behaviour, particularly where it is supposed that a rational choice is done among alternative strategies of action. Accordingly, it has been applied to economic bargaining, political negotiation, the conduct of war, battle of the sexes, etc. Characteristic of game theory is the application of probability considerations to the choice of strategies. What is especially remarkable about this class of models of inquiry is that the mathematics used is essentially so elementary, while the behaviour to which the models usefully apply is complex (Watson, 2002).

4.2. Multi-agent programmable modelling environment with NetLogo

NetLogo is an agent-based programming language and integrated modelling environment. The NetLogo environment enables exploration of complex phenomena. It comes with an extensive models library including models in a variety of domains, such as economics, biology, physics, chemistry, psychology, system dynamics. NetLogo allows exploration by modifying switches, sliders, choosers, inputs, and other interface elements. NetLogo is in use in a wide variety of scientific fields (Railsback & Grimm, 2011).

4.3. Experimental approach in social science

It is a research method that aims to contribute to the understanding of human behaviour by means of controlled laboratory experiments (Vernon Smith, 2008). Data collected in experiments are used to estimate effect, test the validity of theories, and explore market mechanisms. Experiments usually use cash to motivate subjects, in order to mimic real-world incentives. Experiments are used to understand how and why markets and other exchange systems function as they do. Experiments may be conducted in the field or in laboratory settings, whether of individual or group behaviour. Variants of the subject outside such formal confines include natural and quasi-natural experiments.

4.4. Counterfactual methods of causation

Counterfactual method of causation is that the meaning of causal claims can be explained in terms of counterfactual conditionals of the form "If *A* had not occurred, *C* would not have occurred". While counterfactual analyses have been given of type-causal concepts, most counterfactual analyses have focused on singular causal or token-causal claims of the form "event *C* caused event *E*". The best known counterfactual analysis of causation is Lewis's (1973) theory. However, intense discussion over forty years has cast doubt on the adequacy of any simple analysis of singular causation in terms of counterfactuals. Current studies have seen a proliferation of different refinements of the basic idea to achieve a closer match with commonsense judgements about causation (Collin *et al.,* 2004).

4.5. Multiple Working Hypotheses

The method of multiple working hypotheses (MWH) involves the development, prior to our research, of several hypotheses that might explain the phenomenon under study (Chamberlin, 1897). Many of these hypotheses will be contradictory, so that some, if not all, will prove to be false. However, the development of multiple hypotheses prior to the research allows us avoid the trap of the ruling hypothesis and thus makes it more likely that our research will lead to meaningful results. Hence, MWH method suggests all the possible explanations of the phenomenon to be studied, including the possibility that none of explanations are correct and the possibility that some new explanation may emerge. The method of multiple working hypotheses has several beneficial effects because a phenomenon is the result of several causes, not just one; the method of multiple working hypotheses also analyses the interaction of the several causes. The method also promotes much greater thoroughness than research directed toward one hypothesis, leading to lines of inquiry that scholars might otherwise overlook.

The method of multiple working hypotheses can have drawbacks. One is that it is impossible to express multiple hypotheses simultaneously, and thus there is a natural tendency to let one take primacy.

5. Conclusion

Methods of inquiry consider that science advances are essentially due to individual scientists who solve problems, form hypotheses, and do controlled experiments. However, modern science is more and more performed by communities of scholars with international collaboration (Coccia & Wang, 2016). The modern methods of inquiry include many phases in the process of scientific research: study concept, study design and working hypotheses formation, acquisition of data, experiments, analysis and interpretation of data, drafting manuscripts, statistical analyses, critical revision of the project for important intellectual content, obtained funding, administrative, technical and material support and supervision. These complex phases can be distributed across individuals and/or communities of scientist worldwide (e.g., in medicine, astronomy, etc.). Overall, then, modern science is based on a variety of models of inquiry: some scholars focus on history, others on logical analyses, some continue to apply empiricism and state that science advances are concerned with truth only with respect to what can be observed. In general, scientific discovery in modern research fields is multifaceted, requiring diverse processes for generating concepts, for creating new hypothesis and performing controlled experiments. In conclusion, induction, deduction and other methods of inquiry are usually different approaches but never contradictory, often they are complementary tools that facilitate problem solving and knowledge creation within and between research fields.

Notes

[i] For applications of different methods of inquiry in the studies of technology, sources of innovation and management of public research labs, cf., Calabrese *et al.,* 2005; Cariola & Coccia, 2004; Cavallo *et al.,* 2014, 2014a, 2015; Coccia, 2001, 2003, 2004, 2005, 2005a, 2005b, 2005c, 2006, 2006a, 2007, 2008, 2008a, 2008b, 2009, 2009a, 2010, 2010a, 2010b, 2010c, 2010d, 2010e, 2011, 2012, 2012a, 2012b, 2012c, 2012d, 2013, 2013a, 2014, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2015, 2015a, 2015b, 2015c, 2015d, 2016, 2016a, 2016b, 2016c, 2017, 2017a, 2017b, 2017c, 2017d, 2018, Coccia & Bozeman, 2016; Coccia & Finardi, 2012, 2013; Coccia & Wang, 2015, 2016; Coccia & Cadario, 2014; Coccia *et al.,* 2015, 2012, Coccia & Rolfo, 2000, 2002, 2009, 2012, 2007, 2010, 2010, 2013; Coccia & Wang, 2015, 2016; Rolfo & Coccia, 2005.

[ii] See references for application of some of these methods of inquiry in social and human sciences.

[iii] Peirce's canonical statement of his maxim in 'How to Make our Ideas Clear' is: "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of those effects is the whole of our conception of the object". (Peirce, 1992).

[iv] See references for application of some of these methods of inquiry in social and human sciences, such as: Benati & Coccia, 2017; Calabrese *et al.,* 2005; Cariola & Coccia, 2004; Cavallo *et al.,* 2014, 2014a, 2015; Coccia, 2001, 2003, 2004, 2005, 2005a, 2005b, 2005c, 2006, 2006a, 2007, 2008, 2008a, 2008b, 2009, 2009a, 2010, 2010a, 2010b, 2010c, 2010d, 2010e, 2011, 2012, 2012a, 2012b, 2012c, 2012d, 2013, 2013a, 2014, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g, 2015, 2015a, 2015b, 2015c, 2015d, 2016, 2016a, 2016b, 2016c, 2017, 2017a, 2017b, 2017c, 2017d, 2018, Coccia & Bozeman, 2016; Coccia & Finardi, 2012, 2013; Coccia & Wang, 2015, 2016; Coccia & Cadario, 2014; Coccia *et al.,* 2015, 2012, Coccia & Rolfo, 2000, 2002, 2009, 2012, 2007, 2010, 2010, 2013; Coccia & Wang, 2015, 2016; Rolfo & Coccia, 2005.

References

Calabrese, G., Coccia, M., & Rolfo, S. (2005). Strategy and market management of new product development: evidence from Italian SMEs, *International Journal of Product Development*, 2(1-2), 170-189. doi. 10.1504/IJPD.2005.006675

Calderini, M., & Franzoni, C. (2004). Who is patenting in public Research? And to what detriment? An empirical analysis of the relationship between scientific careers and patent applications. *Working Paper Cespri*, No.162. [Retrieved from].

Callon, M., & Foray, D. (1997). Nuvelle economie de la science ou socio-economie de la recherche scientifiche?, *Revue d'Economie Industrielle*, 79(1), 13-32.

Calvert, J. (2004). The idea of basic research in language and practice, *Minerva*, 42(3), 251-268.

Carayol, N., & Matt, M. (2004). Does research organization influence academic production? Laboratory level evidence from a large European university, *Research Policy*, 33(8), 1081-1102. 10.1016/j.respol.2004.03.004

Carraro, F., Pomè, A., & Siniscalco, D. (2001). Science versus Profit in Research: Lessons from the Human Genome Project, *CEPR Discussion Paper*, No.2890. doi. 10.1162/154247603322391215

Cavallo, E., Ferrari, E., Bollani, L., & Coccia, M. (2014). Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system, *Agricultural Systems*, 130, 44-54. doi. 10.1016/j.agsy.2014.05.012

Cavallo, E., Ferrari, E., Bollani, L., & Coccia, M. (2014a). Strategic management implications for the adoption of technological innovations in agricultural tractor: the role of scale factors and environmental attitude, *Technology Analysis & Strategic Management*, 26(7), 765-779. doi. 10.1080/09537325.2014.890706

Cavallo, E., Ferrari, E., & Coccia, M. (2015). Likely technological trajectories in agricultural tractors by analysing innovative attitudes of farmers, *International Journal of Technology, Policy and Management*, 15(2), 158-177. doi. 10.1504/IJTPM.2015.069203

Coccia, M. (2001). Satisfaction, work involvement and R&D performance. *International Journal of Human Resources Development and Management*, 1(2-3-4), 268-282. doi. 10.1504/IJHRDM.2001.001010

Coccia, M. (2003). Metrics of R&D performance and management of public research institute. *Proceedings of IEEE- IEMC 03*, Piscataway, pp.231-236.

Coccia, M. (2004). Spatial metrics of the technological transfer: analysis and strategic management. *Technology Analysis & Strategic Management*, 16(1), 31-52. doi. 10.1080/0953732032000175490

Coccia, M. (2005). Countrymetrics: valutazione della performance economica e tecnologica dei paesi e posizionamento dell'Italia, *Rivista Internazionale di Scienze Sociali*, CXIII(3), 377-412.

Coccia, M. (2005a). Metrics to measure the technology transfer absorption: analysis of the relationship between institutes and adopters in northern Italy. *International Journal of Technology Transfer and Commercialization*, 4(4), 462-486. doi. 10.1504/IJTTC.2005.006699

Coccia, M. (2005b). Technometrics: Origins, historical evolution and new direction, *Technological Forecasting & Social Change*, 72(8), 944-979. doi. 10.1016/j.techfore.2005.05.011

Coccia, M. (2005c). Economics of scientific research: origins, nature and structure, *Proceedings of Economic Society of Australia*.

Coccia, M. (2006). Classifications of innovations: survey and future directions. *Working Paper Ceris del Consiglio Nazionale delle Ricerche*, 8(2), 1-19. [Retrieved from].

Coccia, M. (2006a). Analysis and classification of public research institutes. *World Review of Science, Technology and Sustainable Development*, 3(1), 1-16.

Coccia, M. (2007). A new taxonomy of country performance and risk based on economic and technological indicators, *Journal of Applied Economics,* 10(1), 29-42.

Coccia, M. (2008). Science, funding and economic growth: analysis and science policy implications. *World Review of Science, Technology and Sustainable Development*, 5(1), 1-27. doi. 10.1504/WRSTSD.2008.01781

Coccia, M. (2008a). Spatial mobility of knowledge transfer and absorptive capacity: analysis and measurement of the impact within the geoeconomic space. *The Journal of Technology Transfer*, 33(1), 105-122. doi. 10.1007/s10961-007-9032-4

Coccia, M. (2008b). New organizational behaviour of public research institutions: Lessons learned from Italian case study. *International Journal of Business Innovation and Research*, 2(4), 402–419. doi. 10.1504/IJBIR.2008.018589

Coccia, M. (2009). A new approach for measuring and analyzing patterns of regional economic growth: empirical analysis in Italy. *Italian Journal of Regional Science- Scienze Regionali*, 8(2), 71-95. doi. 10.3280/SCRE2009-002004

Coccia, M. (2009a). Measuring the impact of sustainable technological innovation, *International Journal of Technology Intelligence and Planning,* 5(3), 276-288. doi. 10.1504/IJTIP.2009.026749

Coccia, M. (2010). Public and private R&D investments as complementary inputs for productivity growth. *International Journal of Technology, Policy and Management*, 10(1/2), 73-91. doi. 10.1504/IJTPM.2010.032855

Coccia, M. (2010a). Foresight of technological determinants and primary energy resources of future economic long waves, *International Journal of Foresight and Innovation Policy,* 6(4), 225–232. doi. 10.1504/IJFIP.2010.037468

Coccia, M. (2010b). Energy metrics for driving competitiveness of countries: Energy weakness magnitude, GDP per barrel and barrels per capita. *Energy Policy*, 38(3), 1330-1339. doi. 10.1016/j.enpol.2009.11.011

Coccia, M. (2010c). Spatial patterns of technology transfer and measurement of its friction in the geo-economic space. *International Journal of Technology Transfer and Commercialisation*, 9(3), 255-267. doi. 10.1504/IJTTC.2010.030214

Coccia, M. (2010d). The asymmetric path of economic long waves, *Technological Forecasting & Social Change,* 77(5), 730-738. doi. 10.1016/j.techfore.2010.02.003

Coccia, M. (2010e). Democratization is the driving force for technological and economic change, *Technological Forecasting & Social Change*, 77(2), 248-264. doi. 10.1016/j.techfore.2009.06.007

Coccia, M. (2011). The interaction between public and private R&D expenditure and national productivity. *Prometheus-Critical Studies in Innovation*, 29(2), 121-130. doi. 10.1080/08109028.2011.601079

Coccia, M. (2012). Political economy of R&D to support the modern competitiveness of nations and determinants of economic optimization and inertia, *Technovation,* 32(6), 370–379. doi. 10.1016/j.technovation.2012.03.005

Coccia, M. (2012a). Evolutionary trajectories of the nanotechnology research across worldwide economic players. *Technology Analysis & Strategic Management*, 24(10), 1029-1050. doi. 10.1080/09537325.2012.705117

Coccia, M. (2012b). Evolutionary growth of knowledge in path-breaking targeted therapies for lung cancer: radical innovations and structure of the new technological paradigm. *International Journal of Behavioural and Healthcare Research*, 3(3-4), 273-290. doi. 10.1504/IJBHR.2012.051406

Coccia, M. (2012c). Converging genetics, genomics and nanotechnologies for groundbreaking pathways in biomedicine and nanomedicine. *International Journal of Healthcare Technology and Management*, 13(4), 184-197. doi. 10.1504/IJHTM.2012.050616

Coccia, M. (2012d). Driving forces of technological change in medicine: Radical innovations induced by side effects and their impact on society and healthcare. *Technology in Society*, 34(4), 271-283. doi. 10.1016/j.techsoc.2012.06.002

Coccia, M. (2013). What are the likely interactions among innovation, government debt, and employment? Innovation: *The European Journal of Social Science Research*, 26(4), 456–471. doi. 10.1080/13511610.2013.863704

Coccia, M. (2013a). The effect of country wealth on incidence of breast cancer. *Breast Cancer Research and Treatment*, 141(2), 225-229. doi. 10.1007/s10549-013-2683-y

Coccia, M. (2014). Path-breaking target therapies for lung cancer and a far-sighted health policy to support clinical and cost effectiveness. *Health Policy and Technology*, 1(3), 74-82. doi. 10.1016/j.hlpt.2013.09.007

Coccia, M. (2014a). Emerging technological trajectories of tissue engineering and the critical directions in cartilage regenerative medicine. *Int. J. Healthcare Technology and Management*, 14(3), 194-208. doi. 10.1504/IJHTM.2014.064247

Coccia, M. (2014b). Converging scientific fields and new technological paradigms as main drivers of the division of scientific labour in drug discovery process: the effects on strategic management of the R&D corporate change. *Technology Analysis & Strategic Management*, 26(7), 733-749, doi. 10.1080/09537325.2014.882501

Coccia, M. (2014c). Driving forces of technological change: The relation between population growth and technological innovation-Analysis of the optimal interaction across countries, *Technological Forecasting & Social Change,* 82(2), 52-65. doi. 10.1016/j.techfore.2013.06.001

Coccia, M. (2014). Socio-cultural origins of the patterns of technological innovation: What is the likely interaction among religious culture, religious plurality and innovation? Towards a theory of socio-cultural drivers of the patterns of technological innovation, *Technology in Society*, 36(1), 13-25. doi. 10.23760/2421-7158.2017.004

Coccia, M. (2014e). Religious culture, democratisation and patterns of technological innovation. *International Journal of Sustainable Society*, 6(4), 397-418. doi. 10.1504/IJSSOC.2014.066771

Coccia, M. (2014f). Structure and organisational behaviour of public research institutions under unstable growth of human resources, *Int. J. Services Technology and Management*, 20(4/5/6), 251–266. doi. 10.1504/IJSTM.2014.068857

Coccia, M. (2014g). Steel market and global trends of leading geo-economic players. International *Journal of Trade and Global Markets*, 7(1), 36-52, doi. 10.1504/IJTGM.2014.058714

Coccia, M. (2015). The Nexus between technological performances of countries and incidence of cancers in society. *Technology in Society*, 42, 61-70. doi. 10.1016/j.techsoc.2015.02.003

Coccia, M. (2015a). Patterns of innovative outputs across climate zones: the geography of innovation, *Prometheus. Critical Studies in Innovation*, 33(2), 165-186. doi. 10.1080/08109028.2015.1095979

Coccia, M. (2015b). General sources of general purpose technologies in complex societies: Theory of global leadership-driven innovation, warfare and human development, *Technology in Society*, 42, 199-226. doi. 10.1016/j.techsoc.2015.05.008

Coccia, M. (2015c). Spatial relation between geo-climate zones and technological outputs to explain the evolution of technology. *Int. J. Transitions and Innovation Systems*, 4(1-2), 5-21. doi. 10.1504/IJTIS.2015.074642

Coccia, M. (2015d). Technological paradigms and trajectories as determinants of the R&D corporate change in drug discovery industry. *International Journal Knowledge and Learning*, 10(1), 29-43. doi. 10.1504/IJKL.2015.071052
Coccia, M. (2016). Asymmetric paths of public debts and of general government deficits across countries within and outside the European monetary unification and economic policy of debt dissolution. *The Journal of Economic Asymmetries*, 15, 17-31. doi. 10.1016/j.jeca.2016.10.003
Coccia, M. (2016a). Radical innovations as drivers of breakthroughs: characteristics and properties of the management of technology leading to superior organizational performance in the discovery process of R&D labs. *Technology Analysis & Strategic Management*, 28(4), 381-395. doi. 10.1080/09537325.2015.1095287
Coccia, M. (2016). Problem-driven innovations in drug discovery: co-evolution of radical innovation with the evolution of problems, *Health Policy and Technology*, 5(2), 143-155. doi. 10.1016/j.hlpt.2016.02.003
Coccia, M. (2016c). The relation between price setting in markets and asymmetries of systems of measurement of goods. *The Journal of Economic Asymmetries*, 14(B), 168-178. doi. 10.1016/j.jeca.2016.06.001
Coccia, M. (2017). The source and nature of general purpose technologies for supporting next K-waves: Global leadership and the case study of the U.S. Navy's Mobile User Objective System, *Technological Forecasting and Social Change*, 116, 331-339. doi. 10.1016/j.techfore.2016.05.019
Coccia, M. (2017a). Optimization in R&D intensity and tax on corporate profits for supporting labor productivity of nations. *The Journal of Technology Transfer*, doi. 10.1007/s10961-017-9572-1
Coccia, M. (2017b). Varieties of capitalism's theory of innovation and a conceptual integration with leadership-oriented executives: the relation between typologies of executive, technological and socioeconomic performances. *Int. J. Public Sector Performance Management*, 3(2), 148–168. doi. 10.1504/IJPSPM.2017.084672
Coccia, M. (2017c). Sources of disruptive technologies for industrial change. *L'industria –rivista di Economia e Politicaindustriale*, 38(1), 97-120.
Coccia, M. (2017d). Sources of technological innovation: Radical and incremental innovation problem-driven to support competitive advantage of firms. *Technology Analysis & Strategic Management*, 29(9), 1048-1061. doi. 10.1080/09537325.2016.1268682
Coccia, M. (2017e). A Theory of general causes of violent crime: Homicides, income inequality and deficiencies of the heat hypothesis and of the model of CLASH, *Aggression and Violent Behavior*, 37, 190-200. doi. 10.1016/j.avb.2017.10.005
Coccia, M. (2017f). New directions in measurement of economic growth, development and under development, *Journal of Economics and Political Economy*, 4(4), 382-395.
Coccia, M. (2017g). Disruptive firms and industrial change, *Journal of Economic and Social Thought*, 4(4), 437-450.
Coccia, M. (2017h). The Fishbone diagram to identify, systematize and analyze the sources of general purpose Technologies, *Journal of Social and Administrative Sciences*, 4(4), 291-303.
Coccia, M. (2018). A theory of the general causes of long waves: War, general purpose technologies, and economic change. *Technological Forecasting & Social Change*, 128, 287-295 10.1016/j.techfore.2017.11.013
Coccia, M. (2018a). The relation between terrorism and high population growth, *Journal of Economics and Political Economy*, 5(1), 84-104.
Coccia, M. (2018c). Violent crime driven by income Inequality between countries, *Turkish Economic Review*, 5(1), 33-55.
Coccia, M. (2018d). The origins of the economics of innovation, *Journal of Economic and Social Thought*, 5(1), 9-28.
Coccia, M. (2018e). Theorem of not independence of any technological innovation, *Journal of Economics Bibliography*, 5(1), 29-35.
Coccia, M. (2018e). Theorem of not independence of any technological innovation, *Journal of Social and Administrative Sciences*, 5(1), 15-33.
Coccia, M. (2018f). Classification of innovation considering technological interaction, *Journal of Economics Bibliography*, 5(2), 76-93.
Coccia, M. (2018g). Competition between basic and applied research in the organizational behaviour of public research labs, *Journal of Economics Library*, 5(2), 118-133.
Coccia, M., & Bellitto, M. (2018). Human progress and its socioeconomic effects in society, *Journal of Economic and Social Thought*, 5(2), 160-178.
Coccia, M., & Igor, M. (2018). Rewards in public administration: a proposed classification, *Journal of Social and Administrative Sciences*, 5(2), 68-80.
Coccia, M., & Bozeman, B. (2016). Allometric models to measure and analyze the evolution of international research collaboration. *Scientometrics*, 108(3), 1065-1084. doi. 10.1007/s11192-016-2027-x
Coccia, M., & Cadario, E. (2014). Organisational (un)learning of public research labs in turbulent context, *International Journal of Innovation and Learning*, 15(2), 115-129. doi. 10.1504/IJIL.2014.059756

Coccia, M., Falavigna, G., & Manello, A. 2015. The impact of hybrid public and market-oriented financing mechanisms on scientific portfolio and performances of public research labs: a scientometric analysis. Scientometrics, 102(1), 151-168. doi. 10.1007/s11192-014-1427-z

Coccia, M., & Finardi, U. (2012). Emerging nanotechnological research for future pathway of biomedicine. *International Journal of Biomedical Nanoscience and Nanotechnology*, 2 (3-4), 299-317. doi. 10.1504/IJBNN.2012.051223

Coccia, M., & Finardi, U. (2013). New technological trajectories of non-thermal plasma technology in medicine. *International Journal of Biomedical Engineering and Technology*, 11(4), 337-356. doi. 10.1504/IJBET.2013.055665

Coccia, M., Finardi, U., & Margon, D. (2012). Current trends in nanotechnology research across worldwide geo-economic players, *The Journal of Technology Transfer*, 37(5), 777-787. doi. 10.1007/s10961-011-9219-6

Coccia, M., & Rolfo, S. (2000). Ricerca pubblica e trasferimento tecnologico: il caso della regione Piemonte. *In* S. Rolfo (ed), *Innovazione e piccole imprese in Piemonte*, Franco Angeli Editore, Milano.

Coccia, M., & Rolfo, S. (2002). Technology transfer analysis in the Italian national research council, Technovation - *The International Journal of Technological Innovation and Entrepreneurship*, 22(5), 291-299. doi. 10.1016/S0166-4972(01)00018-9

Coccia, M., & Rolfo, S. (2007). How research policy changes can affect the organization and productivity of public research institutes, *Journal of Comparative Policy Analysis, Research and Practice*, 9(3) 215-233. doi. 10.1080/13876980701494624

Coccia, M., & Rolfo, S. (2010). New entrepreneurial behaviour of public research organizations: opportunities and threats of technological services supply, *International Journal of Services Technology and Management*, 13(1-2), 134-151. doi. 10.1504/IJSTM.2010.029674

Coccia, M., & Rolfo, S. (2013). Human resource management and organizational behavior of public research institutions, *International Journal of Public Administration*, 36(4), 256-268. doi. 10.1080/01900692.2012.756889

Coccia, M., & Rolfo, S. (2009). Project management in public research organization: Strategic change in complex scenarios. *International Journal of Project Organisation and Management*, 1(3), 235–252. doi. 10.1504/IJPOM.2009.027537

Coccia, M., & Wang, L. (2015). Path-breaking directions of nanotechnology-based chemotherapy and molecular cancer therapy, *Technological Forecasting and Social Change,* 94, 155–169. doi. 10.1016/j.techfore.2014.09.007

Coccia, M., & Wang, L. (2016). Evolution and convergence of the patterns of international scientific collaboration. *Proceedings of the National Academy of Sciences of the United States of America*, 113(8), 2057-2061. doi. 10.1073/pnas.1510820113

Collins, J., Hall, E., & Paul, L. (2004). *Causation and Counterfactuals*, Cambridge, Mass: MIT Press.

Dewey, J. (1938). *Logic: The Theory of Inquiry*. Holt, Rinehart and Winston, New York.

Hanson, N.R. (1958). *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science*. Cambridge University Press, Cambridge.

Hempel, C.G. (1965). *Aspects of Scientific Explanation*. The Free Press, New York.

Kaplan, A. (2009). *The Conduct of Inquiry. Methodology for Behavioural Science*. Transaction Publishers, New Brunswick, USA:

Lewis, D. (1973). *Counterfactuals*, Oxford: Blackwell.

Oppenheimer, R. (1955). Analogy in Science. *Presented at the Sixty-Third Annual Meeting of the American Psychological Association*, San Francisco, California, September 4th.

Peirce, C.S. (1992 and 1999). *The Essential Peirce (two volumes edited by the Peirce edition project),* Bloomington: Indiana University Press, 1992–1999.

Popper, C. (1959). *The Logic of Scientific Discovery*, Routledge, London.

Railsback, S.F., & Grimm, V. (2011). *Agent-Based and Individual-Based Modeling: A Practical Introduction*. Cambridge: Princeton University Press.

Rolfo, S., & Coccia, M. (2005). L'interazione fra ricerca pubblica e industria in Italia. L'industria, 26(4), 657-674.

Smith, J.E. (1978). *Purpose and Thought*, Chicago: University of Chicago Press.

Thagard, P. (1988). *Computational Philosophy of Science*. Cambridge, MA (USA): The MIT Press.

Vernon, L., & Smith, A. (2008). *Experimental Economics*. The New Palgrave Dictionary of Economics, 2nd Edition

Watson, J. (2002). *Strategy. An Introduction to Game Theory*. Northon &Company, New York.

West Churchman, C., & Ackoff, R.L. (1950). *Methods of Inquiry: An Introduction to Philosophy and Scientific Method*, Educational Publishers: St. Louis.

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