The impact of inter-, trans- and multidisciplinarity on modern taxonomy of sciences

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The beginnings of taxonomy in the science of the universe, and its rigorous development, emphasizing the role of certain moments, books and personalities, are the subject of the first section. The second section describes the context of the new century, in which interdisciplinarity, transdisciplinarity and multidisciplinarity are amply developing, exponentially widening the universe of scientific research, and generating new and original approaches through new sciences and derived disciplines. In the third part, arguing in favour of the need for principled and adaptive rethinking of the classification of sciences, two taxonomy alternatives are presented, which are graphically called 'iterative' and 'symmetrical (or mirror)', both possible alternatives to the current situation.

Keywords: Iterative and symmetrical, inter-, trans- and multidisciplinarity, science.

SCIENCES and their first attempt at classification or taxonomy became an early reality with Pythagoras, Plato and Aristotle, apparently as simple glances cast onto the world, as speculations or differentiated contemplation divided, by a double approach, into *techne* or science and *episteme* or knowledge, meaning its main activity of the first moving principle, much enhanced in its structure. The sciences of the antiquity finally diluted and fully entered into the composition of Plotinus' soul, where even the activity and the praxis became a mere degraded form of contemplation. Aristotle made a clear distinction between theoretical and practical wisdom, thus generating a long process of discrimination and early taxonomization of *epistemes* (sciences) into *techne* (applied science), nuanced by *poietike* (productive science) or *practice* (practical science) and *theoretike* (theoretical science), opposed to all the gradations above[1].

Half a century ago, Gadamer[2] considered science similar to Aristotle, in a constant search for truth: it may be completely different in the field of hard or natural sciences, where the essential goal was that of forecasting, unlike the so-called soft or spiritual sciences, which have as an objective knowledge 'with no prediction'. Modern science classified sciences, through Penrose[3], more than two decades ago, in a simultaneously Aristotelian and Platonic manner, into only four classes: superb, useful, tentative and misguided/misdirected, seemingly returning to the ancient taxonomy.

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Although the nature and purpose of science are generally the subject of epistemology, and the history of science belongs to scientology, science classification establishes a separate science, usually called taxonomy, which, however, finds itself in a major deadlock. Scientific truth, faith in it and constantly justifying it, are the main issues pursued by epistemology, along with the effective ways of producing scientific knowledge, as well as the characteristic scepticism compared to the degree to which the theoretical goals are achieved, and the stated objectives are met in practical terms. Unlike scientics, the interest of which is placed within the scope of the history of science, science taxonomy attempts to solve a structuring problem of increased difficulty, in the face of multi-, trans-, and interdisciplinary trends, which are ever more dominant in the world of contemporary scientific research. The taxonomy of sciences, built on the Linnaean hierarchic system, logically became the base of the classic system of classification, but it generated itself a matter of intense discussion, and even criticism.

A millennium of history of science taxonomy, from Ikhwan al-Safa' to the Frascati and Oslo manuals

Taxonomy is the science and practice of classification of things, concepts, plants and animals, and even sciences as well, based on the principles and rules that underlie such a classification. Thus, taxonomy is a major component of systematics, encompassing description, identification, nomenclature and classification[4]. Taxonomy uses eight levels in classical botany or zoology (domain, kingdom,

Table 1. Some examples of categories within Biglan's classification

	Hard		Soft	
	Living systems	Non-living systems	Living systems	Non-living systems
Pure	Biology, genetics, physiology, etc.	Physics, mathematics, chemistry, geology, etc.	Psychology, sociology, political science, etc	Philosophy, history, economics, etc.
Applied	Agriculture, medicine, psychiatry, etc.	Engineering, computer science, etc.	Nursing, education, conservation, etc.	Architecture, law, arts, dance, music, etc.

Source: An excerpt from Goel[9].

phylum, class, order, family, genus and species, or D–K–P–C–O–F–G–S), multiplied to as many as 14 in other types of modern biology (rank, division, subdivision, class, subclass, superorder, order, suborder, infraorder, superfamily, family, subfamily, tribe and subtribe). Classical taxonomy has been, and remains, deterministic, defining a simple and coherent model of understanding, representing and explaining the surrounding reality, through structuring and establishing hierarchies, by means of rigorous processes, determined according to clear principles and clear events. The universe of sciences is characterized by infinity, increasing complexity, indeterminism and probability. Generating problematic events, both in nature and in human society, occurs randomly, with a certain probability, and modern sciences are trying to use, in the practical process of solving them, ever more inter-, trans- and multidisciplinary models, which exponentially multiply their number and thus complicate the difficult task of taxonomy. Science taxonomy keeps abreast of the present and draws upon the wealth of knowledge accumulated throughout its history as the classification of sciences, and one brief presentation can find many important personalities, though it cannot provide a complete image without the presence of three major scientists. The first is Ikhwan al-Safa', a high-ranked scholar from the Shi'a community, who is believed to have lived in Basra Iraq, in the 10th century, and who described, in his *Epistles of the Brethren of Purity* (*Rasa'ilIkhwan a-Safa*), two systems of scientific classification[5]: 'the first taxonomy being one of a hierarchical nature, defined by the arrangement of the 52 epistles in the manuscript and their sequence, which contains a higher level of esotericism, and the second was set out by the detailed content of *Epistle VII*'. The two classifications are in fact two lists of significant differences and certain discrepancies from each other, indicating or bearing witness to a historical process of rewriting and re-elaboration. Ikhwan al-Safa' seems to be the first to have defined the necessity, and outlined the utility, of the classification of sciences, mentioning the 'kinds of sciences and the species of those kinds, in such a way that this can be an indication of their objects to those who study the science and in such a way that those people can be rightly guided towards what they are looking at' (in second half of his seventh Epistle). His second system of sciences could be considered a first taxonomy that indicated three kinds of sciences, namely (a) the propaedeutic sciences (the sciences of training and education which were set up mainly for the quest of subsistence and for the goodness of the living in this world, and which are of nine kinds: writing and reading; language and grammar; calculation and operations; poetic and prosody; auguries and auspices, and the like; magic, talismans, alchemy, tricks and the like; professions and crafts; sale and purchase, trades, cultivation and breeding, and biographies and histories); (b) the religious and conventional sciences (the sciences which were set up for the healing of the souls and for the quest of the hereafter; they are of six kinds: the science of revelation; the science of interpretation; narratives and reports; jurisprudence, norms and laws; recollection, exhortations, asceticism and mysticism, and interpretation of dreams), and (c) the philosophical and real sciences (four different species of sciences: mathematics; logic; natural sciences and metaphysics). Ikhwan al-Safa' developed the division of the philosophical sciences as subspecies levels (e.g. mathematics, with its subfields: arithmetic, geometry, astronomy and music), and this underlines the value of his taxonomy.

The second personality in the history of taxonomy of sciences was Charles Sanders Peirce, who elaborated the first modern classification of sciences, inspired by both the Linnaean hierarchic system, and (especially) the biological taxa of Louis Agassiz[6]. As a philosopher, Charles[7] divided science into science of discovery (mathematics, which draws necessary conclusions about hypothetical objects; cenoscopy or philosophy, which details positive phenomena in general, such as confront a person at every waking moment; idioscopy or the special sciences, which describe special classes of positive phenomena, and settling theoretical issues by special experiences or experiments), science of review, and practical science. Peirce used four levels: classes, subclasses, orders, and other taxa (suborders, families). Mathematics was divided in: (a) mathematics of logic; (b) mathematics of discrete series and (c) mathematics of continua and pseudo-continua. Cenoscopy or philosophy used: (a) phenomenology; (b) normative science and (c) metaphysics. Idioscopy or the special sciences included: (a) nomological or

general classificatory; (b) descriptive nomological psychics, or psychology; (c) classificatory psychics, or ethnology and (d) descriptive psychics, or history.

The third personality is psychologist Anthony Biglan, with his memorable scheme of the classification system for scientific disciplines or sciences, based on their differences in preferred research methodologies, the components of those methodologies, and the paradigms underlying them, their application status, and the relation with living systems[8]. Biglan explained some of the differences between scientific disciplines or sciences using three major criteria: (a) Thomas Kuhn's paradigm (this criterion most generally divides scientific disciplines or sciences into hard or paradigmatic and soft or non-paradigmatic, which also points to the divide between natural sciences and humanities or social sciences); (b) the degree of practicality (the status of being or not being applicable) distinguishes between scientific disciplines or sciences that are pure or primarily theoretical (e.g. physics), and simply applied sciences (e.g. engineering); (c) the implicit relationship with living systems (this criterion divides scientific disciplines or sciences into living systems, e.g. agriculture, and non-living systems, e.g. geology. Biglan's taxonomy of scientific disciplines or sciences thus combines the three criteria, finally giving the epistemological and cultural dimension to all of them. Thus this three-layered classification, based on the criteria of hard/soft, living/non-living systems and pure/applied categories, distinguishes all of the scientific disciplines or sciences, the classification being inspired, as shown in Table 1, by a modern and holistic approach[9], and to a lesser extent by a classical one.

Roughly speaking, some classifications similar to Biglan's taxonomy were suggested by others[10–13] as well. The essence of these constructs emphasizes either the importance of the codification or the level of paradigm development, and sometimes even the level of consensus. A modern and generalized taxonomy could be reduced to only five levels, such as class, subclass, family, genus and species form, or may be enlarged to 11 levels or 11 points on a continuum over a population of scientific disciplines or sciences[14,15], isolation (fragmentation, anarchy); awareness (documentation and communication); harmonization (connection, consultation); nesting (infusion); temporal coordination (parallel education or concurrent teaching); sharing (joint teaching); correlation (concomitant or democratic programme); complementary (mixed programmes); multidisciplinary (webbed, contributory); interdisciplinary (monolithic) and transdisciplinary (fusion, immersion, authentic). A specific group of taxonomies of the sciences, including 11 academic discipline classification schemes, was detailed by Braxton and Hargens[16]; three of them are found to have great importance up to this day: (i) the Hagstrom model, based on the idea of disciplinary consensus; (ii) the Hargens model, based on normative and functional integration and (iii) the Zuckerman and Merton model, based on disciplinary codification.

Another important criterion for the taxonomy of sciences was the theory of occupational classification that underlines and uses, for its structure, the skills and abilities of individuals, and thus it classifies not only individuals, but even sciences into six personality types: realistic, investigative, artistic, social, enterprising, and conventional. From this theoretical framework[17], a new taxonomy was born, based on four major levels of the scientific disciplines and sciences: investigative (biology and life sciences, economics, geography, mathematics/statistics, physical sciences, finance, aeronautical engineering, civil engineering, chemical engineering, astronomy, earth sciences, pharmacy, anthropology, ethnic studies, geography, sociology, etc.); artistic (architecture, fine arts (art, drama, music), foreign languages, English, music, speech, theatre, and environmental design); social (ethnic studies, home economics, humanities – history, philosophy, religion, rhetoric, library science, physical and health education, psychology, anthropology, political science, social work, education, etc.) and enterprising (business, communications, computer/information science, law, public affairs, journalism, marketing and industrial engineering).

The most synthetic fields of sciences, used to classify in the contemporary concept of R&D include: natural sciences; engineering and technology; medical and health sciences; agricultural sciences; social sciences (including economics) and humanities (http://www.uis.unesco.org/). There are many general classification schemes like: the universal decimal classification (http://udcdata.info/), the Dewey decimal classification (http://www.oclc.org/dewey/); Dutch Basic Classification (http://www.kb.nl/vak/basis/bc04.pdf), or classifications specialized in economics like: the *Journal of Economic Literature* (JEL), Classification System (http://www.aeaweb.org/journal/jelclasssystem.php).

The overall structure of the scientific disciplines and science classification is related to the organizational structures of universities and other research institutions, and is similar to all the standard and modern guides or manuals, which contain common divisions such as natural sciences, engineering and technology, medical and health sciences, agricultural sciences, social sciences and humanities. However, very much like scientific truth, the methodologies concerning the taxonomy of the sciences or the classification of disciplines, even the most obvious ones have their relative aspects and limits, and are exposed to revision or new changing proposals. Glänzel and Schubert[18] offer a new classification scheme of science fields and disciplines, where the major objectives were met by three successive steps, allowing understanding and feedback throughout the entire taxonomic process: (i) a multilateral 'cognitive' approach (setting the categories), combined with the multiple experience of scientometrics experts; (ii) a multidisciplinary 'pragmatic'

approach, adjusted according to a number of reasonable limits of the economic realities, and (iii) a scientometria approach (relatively unambiguous solutions based on the basic fields/subfield structure of economics as a modern science). The most recent classifications such as the Oslo Manual[19] and Frascati Manual[20] are really relevant for their modern, amalgamated or miscellaneous content, structured on three levels: field, category and subcategory of sciences. The novelty of the revised *Frascati Manual* consists in a breakdown at the second level, which takes into account emerging and interdisciplinary fields, and for which internationally comparable data are sought.

A lot of new sciences, making up the multi-, trans-, and interdisciplinary programmes in education, can be identified in the US Classification of Instructional Programs (CIP), by the National Centre for Education Statistics (NCES). Statistical data and information about the birth of these new sciences from CIP are closest to the idea of the new approach and the specific taxonomy proposed in this article, and can be seen as a new solution for the integration of the new sciences resulted from inter-, trans- and multidisciplinary areas and contexts.

Two taxonomic solutions better suited to the dynamics of multiplication of modern sciences

How can one get to a solution for knowing the general? It seems that Aristotle succeeded in providing an excellent answer to this question through a brilliant parable on the withdrawal of an army from the battlefield: at first, one soldier looks back, and not seeing or hearing the enemy, stops, followed by a second soldier, and a third one, etc. until reaching a certain critical mass will produce the phenomenon of acceptance, as derived from an almost unanimous recognition of reality. It seems that this is how things stand with respect to the specific language of science: reaching a certain critical mass is the element that allows recognition of a new concept in language, recognition of a new paradigm, a new original method or innovative model, and even of a new science emerging as a major impact of aggregated multi-, trans- and interdisciplinary models, investigating a distinct reality, and an area delimited in a completely special way. The second truth seems to be that there is no first essential word in any scientific language, and no single fundamental science in a process of inter-, trans- and multidisciplinarity, will be able to generate a new science, even as a soldier was not more important than the next one in Aristotle's parable.

This article is based on an inter-, trans- and multidisciplinary approach, or on the point of view that involves drawing appropriately from multiple sciences (first of all, 'bi-' or 'tri-' type coagulation, or cross-sectioning of its own areas), to redefine and model phenomena and processes with their specific problems outside of normal boundaries, and reach solutions based on a new holistic understanding of complex situations. This article also proposes two more detailed levels: new 'tri-' sciences as genus (e.g. econobiophysics or econobiopharmaceutics), and new 'bi-' sciences as species (e.g. econophysics or econopharmaceutics) to be added to the levels in the classical Frascati Manual, redefined through biological concepts (domain instead of field, class instead of category, and family instead of subcategory). Thus, the levels of the new taxonomy are: domain, class, family and, because of the impact of inter-, trans- and multi-disciplinarity, genus and species and subspecies. As a synthesis, the proposed taxonomy based on 'inter-, trans- and multi', approaches in modern sciences and derived disciplines could be represented in two different ways, changing the idea of classical taxonomy.

In Figure 1, the first solution, entitled 'iterative taxonomy', can be summed in a double upturned pyramid (like a double funnel), and successively replaced.

The first solution allows to combine classical taxonomy with the new sciences derived from the impact of inter-, trans- and multidisciplinarity, using the two upside-down pyramids (or two funnels).

There is also an alternative solution with two-faced taxonomy or a symmetrical (mirror or butterfly)

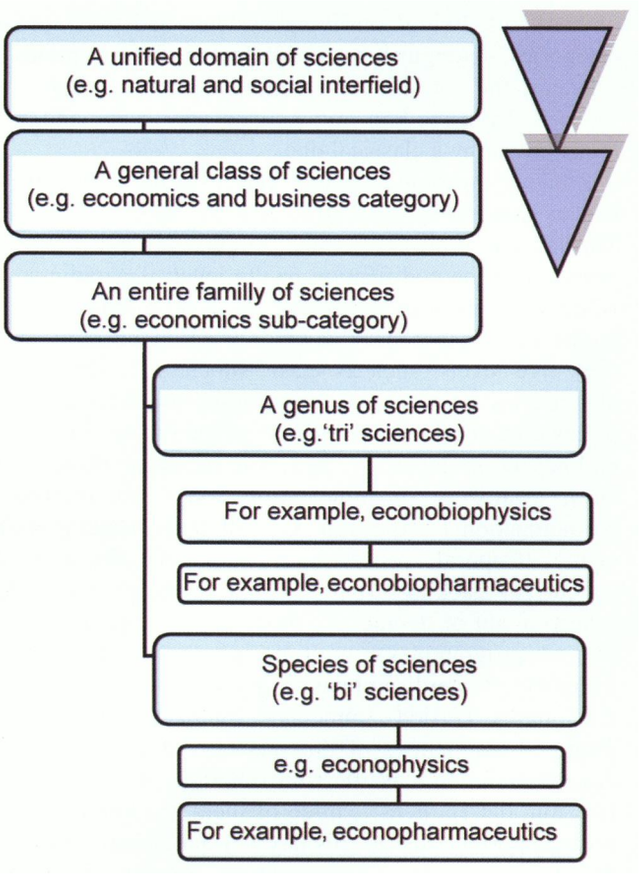

Figure 1. The first option for a modern taxonomy of sciences.

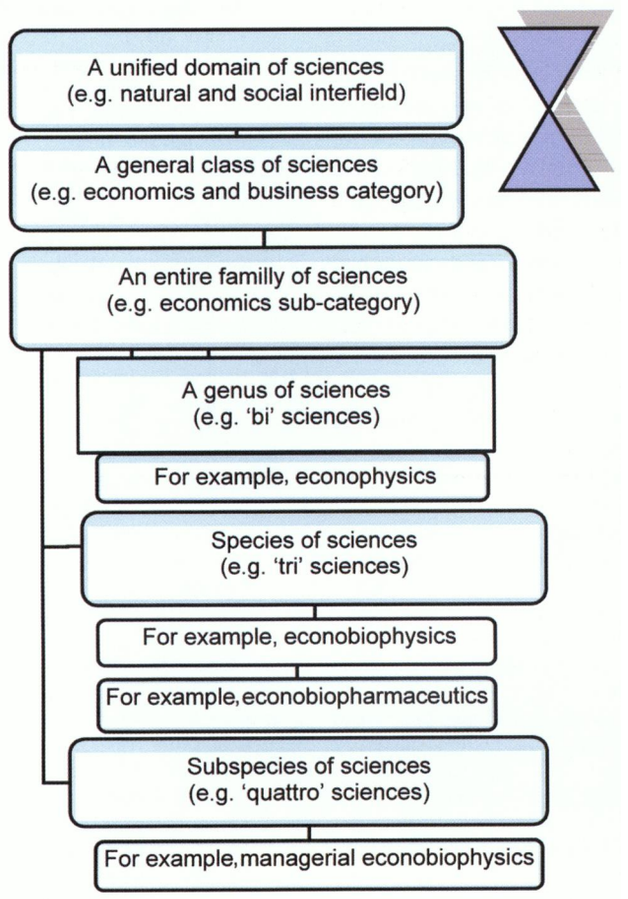

Figure 2. The second option for a modern taxonomy of sciences.

taxonomy, all of it being centred on an entire family of science and allowing adaptation to the evolution of the modern inter-, trans- and multidisciplinary sciences through the formation of new sciences or disciplines that can allow to enlarge the angles of analysis and to create more open scientific investigation over complex contemporary reality, as in Figure 2.

The bi-, tri- or quattro-sciences or scientific disciplines explore the essence of a science family, and each new science implies not only inter-sciences or inter-disciplines, but even a reunion with several other usual categories or subcategories of sciences or disciplines. Classical taxonomy is not able to reflect the changes and the enlarged trend of complex integration under the impact of coagulation or cross-sectioning of different areas of sciences and disciplines. The two new alternatives of the taxonomic solutions must respect the next five major principles:

1. The binomial, trinomial or quattronomial sub-nomenclature of sciences, which could be extended, very much like a so-called contents and linguistics polymerization, where sciences are the molecules. The system follows a major rule: one part of the name defines the genus, the second part designates the species and the third part names the subspecies.

2. The science references indicate their characters, relationships, or membership, combined with clarity or unambiguousness in their designation, uniqueness and taxonomic freedom.

3. The life cycle of the sciences, which underlines that every science has its own life cycle and can be reborn through a hybridization or fusion caused by the inter-, trans- and multidisciplinary process.

4. It requires reaching a critical mass, which should allow redefining and renaming a new science concerning: the existence of (a) a systematic body of knowledge in published books and papers which refer to its specific variables, methods, theory and models; (b) scientists understanding, using and teaching it; (c) researchers in the area applying it, and students studying it; (d) a specific language and literature on it; (e) some communities or associations to further its visions and aims and (f) consensus among all those people implied in field.

5. The double or dual hierarchy and rank, centred on the family or subcategory of science, sciences being hierarchically related, and therefore intrinsically ranked not in a single way, but rather in a double sense (e.g. centred on family or subcategory).

Conclusion

For the modern taxonomy of sciences to survive and prosper, it is necessary to better identify its new entrances or new sciences, its end-users and its functions. The philosophers' minds have often had a native inclination for creating a unified theory of reality and knowledge, and this means a passionate eagerness for the multidisciplinary approach; likewise, the researchers' minds have had a real inclination for plurality and for trans- and interdisciplinary approaches[21]. The modern taxonomy of sciences[22] should possess a little from each of the above, being an appropriate mix of a philosopher and a researcher's way of thinking, and thus should become the 'history of systems of thought'.

1. Săvoiu, G., Principles, landmarks and stages of scientific research in the field of economics, which were finalized by papers published in prestigious journals, *Amfiteatru Econ.*, 2013; http://www.amfiteatrueconomic.ro/Landmarks_of_economic_research.aspx (retrieved on 15 November 2013), pp. 1–13.
2. Gadamer, H. G., *Hermeneutik II: Wahrheit und Methode*, Tübingen: Mohr (Siebeck), 1993, p. 15.
3. Penrose, R., *The Emperor's New Mind, Concerning Computers, Minds, and the Law of Physics*, New York, Oxford University Press, Oxford, 1989, p. 189.
4. Simpson, M. G., *Plant Systematics*, Elsevier Academic Press, London, UK, 2010, 2nd edn, p. 9.
5. De Callataÿ, G., *The Classification of the Sciences according to the Rasa'il Ikhwan al-Safa'*. Université Catholique de Louvain, Institut Orientaliste, Faculté de Philosophie et Lettres, Louvain-la-Neuve; http://www.iis.ac.uk/SiteAssets/pdf/rasail_ikhwa.pdf (retrieved on 10 October 2013), pp. 1–13.
6. Agassiz, L., *Essay on Classification* (ed. Lurie, E.), The Belknap Press of Harvard University Press, Cambridge, Massachusetts, USA, 1962.
7. Peirce, C. S., A detailed classification of the sciences. *Collected Papers*, 1903, **1**, 180–202.
8. Biglan, A., The characteristics of subject matter in different academic areas. *J. Appl. Psychol.*, 1975, **57**(3), 195–203.
9. Goel, S., Well rounded curriculum – an insight from Biglan's classification of disciplines; http://goelsan.wordpress.com/2010/07/27/biglans-classification-of-disciplines/ (retrieved on 18 November 2013).
10. Becher, T., *Academic Tribes and Territories: Intellectual Enquiry and the Cultures of the Disciplines*, Society for Research into Higher Education, Open University Press, Buckingham, England, 1989, pp. 186–188.
11. Becher, T. and Trowler, P. R., *Academic Tribes and Territories: Intellectual Inquiry and the Culture of Disciplines*, Open University Press, Buckingham, England, 2001, 2nd edn, p. 126.
12. Huggan, G., Mixing disciplines: the anxiety of interdisciplinarity. *Postcolonial Stud.*, 2002, **5**(3), 256–313.
13. Schommer-Aikins, M. *et al.*, Epistemological beliefs across domains using Biglan's classification of academic disciplines. *Res. Higher Educ.*, 2003, **44**(3), 352–353.
14. Harden, R., Integrated teaching – what do we mean? A proposed taxonomy. *Med. Educ.*, 1998, **32**, 216–217.
15. Harden, R. and Davis, M. H., The continuum of problem-based learning. *Med. Teach.*, 1998, **20**(4), 317–322.
16. Braxton, J. and Hargens, L., Variation among academic disciplines: analytical frameworks and research. In *Higher Education: Handbook of Research and Theory* (ed. Smart, J.), Agathon Press, New York, 1996, vol. 11, pp. 1–46.
17. Lattuca, L. R. *et al.*, Academic environments in detail: Holland's theory at the subdiscipline level. *Res. Higher Educ.*, 2010, **51**(1), 21–39.
18. Glänzel, W. and Schubert, A., A new classification scheme of science fields. *Scientometrics*, 2003, **56**(3), 357–367.
19. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. The Measurement of Scientific and Technological Activities*, OECD Publishing, 2005, 3rd edn, pp. 63–73.
20. *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development, The Measurement of Scientific and Technological Activities*, OECD Publishing, 2002 (*revised* 2007); http://www.oecd.org/science/inno/38235147.pdf (retrieved on 16 November 2013), pp. 6–12.
21. Săvoiu, G., *Econophysics: Background and Applications in Economics, Finance, and Sociophysics*, Elsevier Academic Press, London, UK, 2012, pp. 17–28.
22. Foucault, M., *The Order of Things: An Archaeology of the Human Sciences*, A translation of *Les Mots et les Choses*, Vintage Books, A Division of Random House, Inc, New York, 1970, p. x.

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