ECOLOGICAL MODEL OF ROMANIAN RESEARCH AND EDUCATION – A SYSTEMIC APPROACH

PETRIŞOR Alexandru-Ionuţ

Abstract. The term "research ecosystem" seems to have been used extensively in the recent period. A review of its usage indicates that professionals from the health system, information sciences, librarians and politicians have embraced it mostly. However, from the standpoint of social/human ecology, it is legitimate to question its use. A literature review indicates that most of the people using it simply adapted to the fashion and did not develop a model of the system; instead, they understand the web of relationships among researchers and the publishing web (scientific production and citations). Starting from the Romanian example, this paper attempts to use the principles of systemic ecology to develop a model of the "research ecosystem" as a subsystem of the socioeconomic system, identifying the components and their relationships, but also the main functions: circulation of information and money, and self-regulation, in the context of its dynamic.

Keywords: human ecology, social ecology, research ecosystem, systemic ecology, homomorphous model.

Rezumat. Model ecologic al sistemului românesc de cercetare-învăţământ – o abordare sistemică. Termenul „ecosistem de cercetare" pare să fie utilizat din ce în ce mai mult în ultima vreme. O analiză a utilizării sale indică predilecţia celor din domeniul medical, al tehnologiei informaţiei, al biblioteconomiei şi a politicienilor pentru folosirea sa. Totuşi, este legitim să ne punem problema legitimităţii folosirii sale din punctul de vedere al ecologiei sociale/umane. O sinteză a literaturii de specialitate arată că cei mai mulţi îl folosesc în virtutea modei, fără a avea un model clar al sistemului, axându-se doar asupra relaţiilor dintre cercetători şi reţelei literaturii de specialitate (producţie ştiinţifică şi citări). Pornind de la exemplul României, acest articol îşi propune utilizarea principiilor ecologiei pentru elaborarea unui model al „ecosistemului de cercetare" ca subsistem al sistemului socio-economic uman, identificând componentele şi relaţiile dintre acestea, dar şi principalele funcţii – circuitul informaţiei şi banilor – în contextul dinamicii sistemului.

Cuvinte cheie: ecologie umană, ecologie socială, ecosistem de cercetare, ecologie sistemică, model homomorf.

INTRODUCTION

Contemporary research involves more and more, to the extent of relying to the transfer of concepts and methods between different disciplines, leading ultimately to the emergence of new ones, and even to complexity sciences, such as Haken's synergetics (PETRIŞOR, 2013b). Most authors consider that the cooperation between different disciplines is a multi-staged process, starting with the multi-disciplinary approaches, when despite the transfers disciplines speak as separate voices, then inter-disciplinary approaches unite them, and ultimately trans-disciplinary approaches produce an unifying synthesis and lead to the emergence of new disciplines (BESSELAAR & HEIMERIKS, 2001; BRUUN et al., 2005; CHOI & PAK, 2006, 2007, 2008; LATTANZI, 1998; NICOLESCU, 2005; PETRIŞOR, 2013b; ZAMAN & GOSCHIN, 2010).

Such transfers were proven to be productive and useful, despite the fear of some disciplines (e.g., geography) that they would result into the loss of their object of study (IANOŞ, 2000; PETRIŞOR, 2011). Among the disciplines "exporting" most concepts to the other, ecology occupies perhaps one of the first places. Not only other sciences started using the concepts and jargon of ecology, but even the pop culture; expressions like "food chain" or "bottom feeder" extended their meaning to encompass any ranking system, respectively an irresponsible person who lives at the expense of the others (MERRIAM-WEBSTER, 2014).

Among the disciplines benefitting upon such transfers, the first is economy. This should be no wonder at all, provided that Haeckel's definition of ecology builds up the new science on the same "*οικος*" (HAECKEL, 1866). The relationship between the two disciplines gave birth to ecological economics, discipline dealing with the relationship between man-dominated and natural systems under the framework of sustainability (COSTANZA et al., 1991; HEZRI & DOVERS, 2006), underlining the importance of natural systems for economy (TSCHIRHART, 2009), but also with applying ecological models to the economic systems and economic models to the natural systems (COSTANZA et al., 1991; TSCHIRHART, 2009). Out of the many concepts of ecology, trophic relationships were particularly attractive; they were found similar to social networks (DE CARVALHO DUARTE, 2013), to the relationships between languages (LAPONCE, 1993), to political relationships (CORNING, 1996), or to the interactions between different industrial technologies (BALDWIN et al., 2004; LIWARSKA-BIZUKOJCA et al., 2009; SANDÉN & HILLMAN, 2011) or cities (IANOŞ, 2000; IANOŞ & HELLER, 2006).

This research focuses on the emergence of a new concept – "the research ecosystem". The underlying hypothesis is that the new concept is more than a simple "trendy word", and that despite its misunderstanding the research, development and innovation system can be seen as a sub-system of the socio-economic system, and consequently the application of the principles of social/human ecology can allow for sketching a structural and functional model of it, preceding a homomorphous model.

RESEARCH ECOSYSTEM: TERM & CONCEPT – A LITERATURE REVIEW

Although the term “research ecosystem” seems to be used extensively, especially during the recent period, an in-depth literature review indicates that there are differences between the disciplines using it in terms of intensity, degree of conceptualization and understanding.

The concept is present in the political discourse regardless of the country (Romanian Ministry of National Education, 2013; WILLETTS, 2012), and also in different disciplines: library science and scientometry (BRADBURY & WEIGHTMAN, 2010; FENNER & LIN, 2014; GALLOWAY & PEASE, 2013; PULVERER, 2013), health care and medicine (HAWKES, 2014; PARCIANELLO et al., 2013; LIM, 2014; POTKAR, 2014; ROSENBERG, 1999; SULLIVAN et al., 2010; THOMPSON & MOSKOWITZ, 1997), information technology and science (HAAK et al., 2012; KRESTYANINOVA & TAMMISTO, 2012; ÖSTERLE & OTTO, 2010; QUAGGIOTTO, 2008; SMITH et al., 2011; SWAN, 2012; TICKELL, 2013), languages and literature (FLECKENSTEIN et al., 2008), music (DE ROURE, 2011), social sciences (JOHNSON, 2013), education sciences (SIDHU, 2009), or even generalizations beyond the disciplinary boundaries (BOCCANFUSO, 2010; JANSSON & RYYNÄNEN, 2013; RAMANARAYANAN, 2010; RODRIGO et al., 2013).

Nevertheless, few of these authors clearly define, or at least attempt to enumerate the components. Most of them simply use the term “research ecosystem” – generalized or referring to a specific discipline (ROSENBERG, 1999; THOMPSON & MOSKOWITZ, 1997) – or some similar terms: innovation ecosystem (ÖSTERLE & OTTO, 2010; ROSENBERG, 1999); research and development ecosystem (HAAK et al., 2012), digital research ecosystem (DE ROURE, 2011), or research, development and innovation ecosystem (Romanian Ministry of National Education, 2013). The views are very unclear and diverse, sometimes less structured or explicit.

Despite the diversity, some trends can be distinguished; information scientists and librarians perceive the research ecosystem mostly as a web of publications (FENNER & LIN, 2014; PULVERER, 2013; Romanian Ministry of National Education, 2013; TICKELL, 2013) or publications and their citations (BRADBURY & WEIGHTMAN, 2010; GALLOWAY & PEASE, 2013), underlining the importance of “taxonomy” introduced by unique identifiers, such as ORCID (Open Researcher and Contributor ID) for tracking down the impact of individual or group research (BRADBURY & WEIGHTMAN, 2010; GALLOWAY & PEASE, 2013), and metrics (e.g., impact factor) – PULVERER, 2013.

Other researchers focus on the collaborative relationships between researchers, and see the “research ecosystem” as a collaborative web (FLECKENSTEIN et al., 2008; JANSSON & RYYNÄNEN, 2013; KRESTYANINOVA & TAMMISTO, 2012; LIM, 2014; QUAGGIOTTO, 2008; RODRIGO et al., 2013; Romanian Ministry of National Education, 2013; SMITH et al., 2011; WILLETTS, 2012), eventually underlining the role of incubators in facilitating cooperation (RODRIGO et al., 2013), or nexus of related studies (SWAN, 2012) or mapping them (QUAGGIOTTO, 2008).

For the very few to name components, opinions are in disagreement. For HAAK et al. (2012), the “research ecosystem” is a digital web of information, consisting of inputs, outputs, activities, and external factors, and data (note that the “black box” approach was obviously preferred by information sciences, since it is similar to the computer programming concepts). Other components include research and technology (DE ROURE, 2011), conceptualizations, data collection, coding, conclusions, and reporting (JOHNSON, 2013), lives of people who are part of it (FLECKENSTEIN et al., 2008), players and interests (SULLIVAN et al., 2010) or accreditation (POTKAR, 2014). The Romanian Ministry of National Education (2013) lists most components: program-related authorities, monitoring committees, central government, European Commission, international organisms, national and international research community, national and international evaluators, funding beneficiaries, national and international investors, civil society and broader public.

In terms of controversies, for RAMANARAYANAN (2010), the “research ecosystem” is an undifferentiated mix of components and outputs, namely education and research (particularly sponsored), theses, dissertations, publications, courses; the importance of funding is also stressed out by ÖSTERLE & OTTO (2010), and raises the question whether the economy or government, providing the funds, are part of the research ecosystem or not. On a similar note, BOCCANFUSO (2010) includes universities and industry, SIDHU (2009), centres of excellence in research, domestic industry and multinational corporations, and HAWKES (2014), government, charities, and industry; it is interesting to see that the opinion of HAWKES (2014) is somehow different from the viewpoint of WILLETTS (2012), who mentions charities, data and objects, research publishers, although both refer to the research system of the United Kingdom. Another interesting aspect is that charities are seen as part of the research ecosystem only in the United Kingdom (HAWKES, 2014; WILLETTS, 2012). In opposition to all these, the model of the triple helix (ETZKOWITZ & LEYDESDORFF, 1996, 2000; JANSSON & RYYNÄNEN, 2013) distinguishes three separate systems: state/government, research and education, economy/industry; innovation.

Another controversy is the typology. For information scientists (again) – but not only, the “research ecosystem” is a digital ecosystem (since it is perceived as a literature or collaboration web only) – DE ROURE, 2011; QUAGGIOTTO, 2008; SMITH et al., 2011; for others, it is a socio-technical ecosystem, part of the industrial ecosystem – again, in contrast with the discussion from the previous paragraph (SULLIVAN et al., 2010).

Only few authors take the analogy even further. BUTLER (2013) discusses the concept of “predatory journals”. ROSENBERG (1999) sees the “endangered physician-scientist” as a “lost species” in the nation’s medical research ecosystem. PARCIANELLO et al. (2013) develop a systemic approach, consisting mostly of identifying the structural elements (components and relationships) and apply it to intensive care units in order to ensure their sustainability. Perhaps the most interesting and complete analogy is made by FLECKENSTEIN et al. (2008), who analyze research and writing from the perspective of ecology, focusing on relationships; their analogy includes the circulation of information, the self-regulatory processes, resilience and productivity, and importance of diversity.

RESEARCH ECOSYSTEM: TOWARDS A STRUCTURAL AND FUNCTIONAL MODEL

The previous literature review indicated that very few of the authors who used the term "research ecosystem" had a clear ecological perspective of it. Most of them probably found its use "trendy" and in line with the new literature and political language. In fact, the ecological perspective itself needs to be discussed further. The understanding of ecology and ecosystems has evolved, although some people did not want to change; the original focus was on components and relations both in Haeckel's definition of ecology (HAECKEL, 1866): *relations of the organism to the environment including, in the broad sense, all the* "*conditions of existence*", and Tansley's definition of the ecosystem (TANSLEY, 1935): *not only the organism-complex, but also the whole complex of physical factors forming what we call the environment*. Despite the evolution of ecology, many people remain tributary to the original definition, such as ANDREWARTHA & BIRCH (1954), who simply add several functions of the ecosystems. However, ecology stepped to a new era, when the systemic approach became a necessity; therefore, the structure, functions, and relationships with the integrated subsystems and integrating supra-systems must be accounted for (PETRIŞOR, 2013a).

As it can be seen, for the vast majority of the authors analysed before – except for PARCIANELLO et al. (2013) and FLECKENSTEIN et al. (2008) – the research ecosystem is seen from the standpoint of the original and minimal perception of a system as components and relationships. In the following paragraphs, the principles of systemic ecology are applied to describe the research ecosystem as a sub-system of the socio-economic system in terms of structure, functions, dynamics, and relationship with other sub-systems of the socio-economic system.

Ranking in the ecological hierarchy. As stressed out before, the "research ecosystem" is part of the socio-economic system, which is also coupled to the natural systems. Previous studies have showed that coupling results basically in the addition of levels to the trophic scale: the natural scale includes mineral, vegetal, and animal trophy, while the socio-economic system adds techno-trophy – economy, industry, and noo-trophy – knowledge, management and other support processes, with resources and energy taken from the natural systems (IANOŞ, 2000; PETRIŞOR & SÂRBU, 2010; PETRIŞOR, 2012). A similar model is proposed by MILLER (1978), who distinguished seven organizational levels of the living world (including socio-economic systems): cell, organ, organism, group, organization, society and the supra-national system. Although the first approach suggests that research is superior to basic economic and industrial activities, it does not necessarily imply a different hierarchical position of the "research ecosystem" compared to the "economic ecosystem". In the model proposed in figure 1, all systems – research, industry/economy, government, and society are equal in rank and overlap. This relationship is based on the triple helix model proposed by ETZKOWITZ & LEYDESDORFF (1996, 2000).

With respect to the relationships between the "research and education ecosystem" – and its components – and the other systems, the model shows that the research ecosystem provides knowledge transferred into products to the industry, receiving funds from it for this purpose, and provides – along with the education ecosystem – knowledge and expertise to the government (for the substantiation of public policies) and society. At the same time, the government funds both education and research. Education is generating welfare (at least for the purpose of better salaries proportional to the level of education, although this is not the only mechanism). An indirect mechanism relates research to research via the industry – production of laboratory equipment and technology.

Structure and functions. Figure 1 displays the components and flows, using the symbols of homomorphous models. The image displays stocking and circulation/transfer components; the flows consist of money and information (knowledge). Some of the transfers are part of the cycles, while others can be seen as losses.

For example, predatory journals - term assigned to Jeffrey Beall (2008) – which have increased their effectives significantly in 2012 exploit community by charging fees (BUTLER, 2013); while other mainstream journals do the same (charging authors or readers), established authors consider a paper published in these journals "loss" due to their lack of a competent peer-review system (in plain words, they are likely to publish anything as long as the author pays the charges). The analogy can be continued with reference to the five stages of predation (ENDLER, 1986): detection, identification, approach, subjugation, and consumption; "detection" consists of looking for potential victims among authors who have published in other journals; "identification" consists of getting the full name and e-mail address (or only the latest); the "approach" is a personalized or mass e-mail; "subjugation" consists of a multitude of approaches, such as upraising the author or mimicking already established journals; "consumption" ends with receiving the author's money. The predation strategies are somehow similar to the ones in the biological realm.

Similarly, with respect to the research system, administration and management (dealing with the research policies and management of research funds) are not directly productive and often seen by researchers as a burden; on the other hand, they are socially efficient, as they absorb human resources and contribute to reducing unemployment.

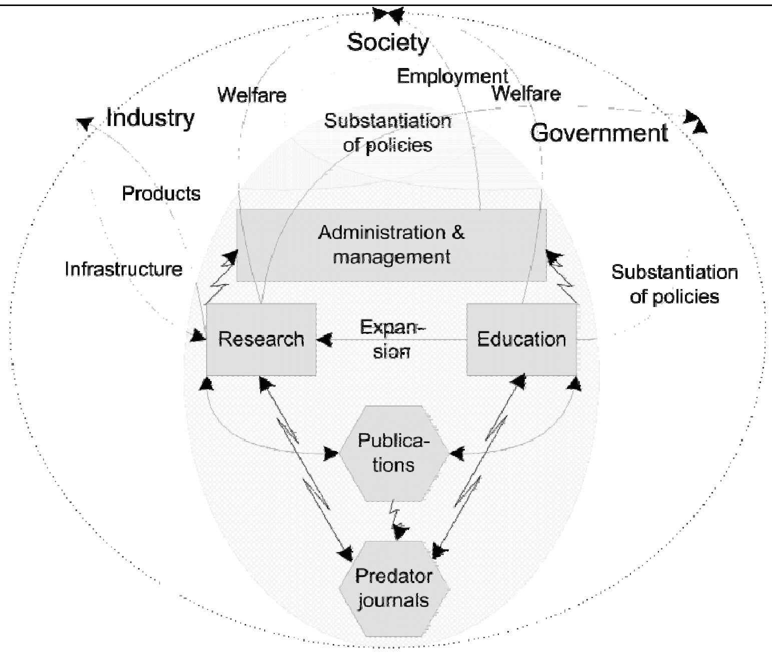

Figure 1. Model of the Romanian research and education ecosystem, as a subsystem of the socioeconomic system. The image shows related "ecosystems" (society, economy/industry, and administration/government, as in the model of the "triple helix" – ETZKOWITZ & LEYDESDORFF, 2000). Zigzag arrows indicate "losses" (one-way transfers); hexagons symbolize stocking compartments, and rectangles correspond to cycling/transfer compartments. All arrows suggest the direction of information and money flows.

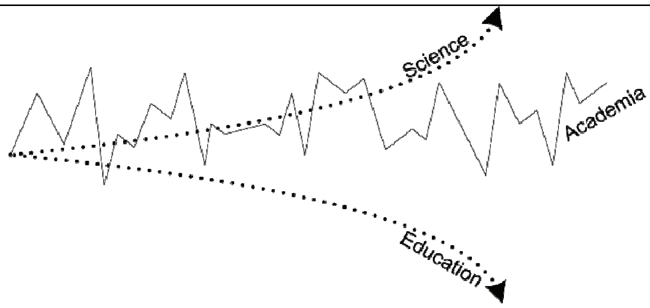

Figure 2. Dynamics of the Romanian education system (full line). Dotted arrows indicate the main attractors.

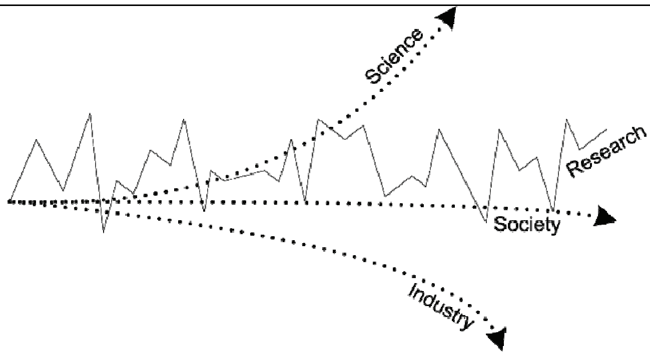

Figure 3. Dynamics of the Romanian research system (full line). Dotted arrows indicate the main attractors.

The relationship between the education and research components is somehow controversial. According to the Romanian legislation, both educational and research activities are present in the "job description" of universities, while research entities are confined to research. The recent trend can suggest an expansion of research in universities – i.e., the 2011 research-based classification of universities as (1) education-focused, (2) education and research or art, (3) advanced research and education (Parliament of Romania, 2011).

An important stocking compartment is the scientific literature; its primary role is to stock knowledge, although eventually knowledge is circulated (e.g., "old" theories and methods are re-discovered, sometimes after long periods). However, the cryptic scientific jargon makes hard for the industry, government, or society to access the knowledge directly. A special chapter – popularized literature – plays this role.

Dynamics and self-regulation. The two sub-systems – research and education – have different dynamics. As it has been shown above, while the primary mission of universities is education, the 2011 changes indicated a clear shift to research (Fig. 2). Additional pressures are exercised by the market, resulting into favouring some disciplines in the detriment of the others. In a similar way, according to the triple helix model (ETZKOWITZ & LEYDESDORFF, 1996; 2000), government and economy/industry are potential attractors determining the dynamics of research. Nevertheless, it has to be stressed out that research has basically three functions: scientific progress – basic research ("for the sake of research" or to bypass technological blockages), economic development (attraction exercised by the industry), and societal progress (and welfare) – DOS REMEDIOS, 2006; GODIN & DORE, 2005; Global Science Forum, 2014. These pillars are represented in figure 3, showing the dynamics of research.

Although self-regulation is a function, it is discussed here, as the dynamics of the research and education systems is influenced by other systems, and in this context the role of self-regulation is to preserve the homeostasis of each component. For instance, given the additional research pressure exercised over the education system, not only through the 2011 classification of universities, but especially through research-focused promotion criteria (based on the number of high-level publications and, more recently, citations), the system tried to adapt by replacing quality with quantity. For example, the 2005 criteria were amended in 2006 to introduce "equivalents": a Thomson-ISI indexed article was equalled to a certain number of papers published in nationally recognized journals, varying based on the discipline. Similarly, the 2011 criteria accounting for publishing in top-rated journals were changed in 2012 to account for publication of Thomson-ISI indexed articles, regardless of their metrics. All these examples show a certain resistance to change of the research system, but also the fact that its equilibrium is dynamics.

It is also important to see that the laws of thermodynamics apply to the research ecosystem similar to the natural ones, but with changed parameters. Ecosystems – natural or man-dominated – are dissipative structures, using energy to increase their diversity and complexity, and have an anti-entropic behaviour; in particular humans tend to organize their surrounding space (IANOŞ & HUMEAU, 2000). This is also obvious in the research ecosystem, where "complexity" and "diversity" translate in the hierarchies and rankings (research, didactic), in the increased complexity of the publishing system (*e.g.*, peer review) or projects (including administrative, managerial, dissemination and financial components). In this case, the direct information circuit (and, indirectly, the circuit of money) can be measured directly using Shannon-Wiener's informational entropy, accounting for the fact that the amount of information, in correlation with the informational energy (directly) and informational entropy (inversely, because information is obtained from the production of entropy), measure the complexity and inner organization (MARCUS, 2011). Moreover, all these imply that the "research ecosystem" is open and far away from the thermodynamic equilibrium; therefore if the analogy with natural ecosystems is continued, entropy can be used for measuring the inner organization (MARCUS, 2011).

Metrics. As it could be seen in the previous paragraph, the "ecology of research" measures the relationship through a variety of metrics, looking at the productivity (scientific production, money transfer to/from economy), or its impact (at the level of publications – impact factor, article influence score, or at the level of researchers and groups – Hirsch index). Although the usage of research metrics is extensive, some people show that they have many shortcomings; for example, if the economic value is accounted for, one must recall that scientific activities are not directly-productive (CORLAN, 2005). On the other hand, if the metrics of the scientific production are used, one must know that they are not necessarily objective and that their use resulted into unethical behaviour (LAWRENCE, 2007).

CONCLUSIONS

This research attempted to apply the principles of systemic ecology to develop a model of the "research ecosystem" as a subsystem of the socioeconomic system, identifying the components and their relationships, but also the main functions. The main components had different functions; research, education, and "parasitic" administrative infrastructure contribute to cycling/transferring money and information to and from society, economy/industry and administration; publishing – including the "predatory journals" – serves as a stock of information (and money). The dynamics of the research and education system is influenced by its relationship with society, administration and industry; in the model of the "triple helix", the last two and research/education form a unit that fuels the knowledge-based economy. At the same time, the societal, economic and scientific values of research play an important role in its dynamics.

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Petrişor Alexandru-Ionuţ
Department of Urban and Landscape Planning, School of Urban and Landscape Planning.
“Ion Mincu” University of Architecture and Urbanism
Str. Academiei. no. 18-20. sector 1. cod 010014. Bucharest. Romania.
National Institute for Research and Development in Constructions, Urbanism and Sustainable Spatial Development URBAN-INCERC
Șos. Pantelimon no. 266. sector 2. cod 021652. Bucharest. Romania.
E-mail: alexandru_petrisor@yahoo.com, Internet: www.environmetrics.ro

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