INNOVATION ECOSYSTEMS IN THE EUROPEAN UNION: TOWARDS A THEORETICAL FRAMEWORK FOR THEIR STRUCTURAL ADVANCEMENT ASSESSMENT *

Sara González Fernández, ** Renata Kubus, ***
Juan Mascareñas Pérez-Iñigo ****

Summary: A theoretical framework to describe and assess the advancement of innovation ecosystems in the contemporary European Union is more than necessary in order to map actors and processes, and thus provide a more comprehensive and dynamic approach. For actors, the reframed innovation helix perspective is applied, while the multilevel perspective is used for processes. At each innovation progress stage, other actors should have a slightly different role, be more active and important, and also relate to each other in a different manner. The emergence and density of intermediary actors are seen as important aspects. From the process perspective, the innovation application and also its adoption at the sociotechnical landscape level are seen as crucial. Thus, collective intelligence with societal implications and consideration for the environment evolve into the key ingredients of an advanced innovation ecosystem in the European Union.

1 Introduction

It is a challenge to describe innovation ecosystems and the way they function in a comprehensive manner. The awareness that a knowledge-based[1] or information[2] society functions according to different sets of dynamics from an industrial society focused mainly on manufacturing tangible goods[3] has become increasingly important. New knowledge

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** Universidad Complutense de Madrid, saragon@ccee.ucm.es, https://orcid.org/0000-0002-3274-7980.

*** Universidad Nacional de Educación a Distancia (España), de_renata@yahoo.de, https://orcid.org/0000-0002-7133-8290.

**** Universidad Complutense de Madrid, jmascare@ucm.es, https://orcid.org/0000-0001-5548-6309.

[1] A term popularised by Peter Drucker in his book *The Age of Discontinuity* (Butterworth-Heinemann 1969).

[2] A term popularised by Fritz Machlup in *The Production and Distribution of Knowledge in the United States* (Princeton University Press 1962).

[3] Henry Etzkowitz, *The Triple Helix: University–Industry–Government Innovation in Action*, vol 42 (Routledge 2008) 18.

is destabilising existing system elements and dynamics (which are rather stable in an industrial economy) and making them evolve very rapidly.

In order to describe this dynamic, it is necessary to define the meaning of a broad innovation ecosystem.[4] In comparison to the innovation system approach, the innovation ecosystem line of study implies a more organic and evolving structure, depending on the conditions of each of its dimensions. An ecosystem is 'an accommodation to the dilemma of reconciling social and biological facts in understanding our species'.[5] It also entails the perspective of the (natural) environment[6] as something not necessarily always considered in the economic field. It challenges, as well, the perspective of the system's openness, shifting to a closed one with the need for a circular approach.[7]

There is a long history of the use of the term 'innovation', starting with Schumpeter's views from the beginning of the last century that it is:

> a new combination of productive elements with an industrial but also commercial application — a new product, process or technique of production; a new market or source of materials or supply; a new form of commercial business or financial organisation.[8]

For Milbergs:

> Innovation is a process by which value is created for customers through public and private organizations that transform new knowledge and technologies into profitable products and services for national and global markets. A high rate of innovation in turn contributes to more intellectual capital, market creation, economic growth, job creation, wealth, and higher standard of living.[9]

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[4] Deborah J Jackson, 'What Is an Innovation Ecosystem?' [2011] Engineering Research Centers, National Science Foundation 1.

[5] Gary E Machlis, Jo Ellen Force and William R Burch Jr, 'The Human Ecosystem Part I: The Human Ecosystem as an Organizing Concept in Ecosystem Management' (1997) 10(4) Society & Natural Resources 347, 350.

[6] The relevance of the natural environment can be confirmed by the actions taking place related to the Paris Agreement. For instance, European Commission, 'The road from Paris: Assessing the implications of the Paris Agreement and accompanying the proposal for a Council Decision on the signing, on behalf of the European Union, of the Paris Agreement adopted under the United Nations Framework Convention on Cl' (Communication) COM (2016) 110 final, 1 <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:52016DC0110&from=EN> accessed 14 September 2018.

[7] Kenneth Boulding, 'The Economics of the Coming Spaceship Earth' (Sixth Resources for the Future Forum on Environmental Quality in a Growing Economy, Washington, DC, March 1966 <www.panarchy.org/boulding/spaceship.1966.html> accessed 14 September 2018.

[8] Joseph Schumpeter, *Theorie Der Wirtschaftlichen Entwicklung* [*The Theory of Economic Development*] (Duncker & Humblot 1911) 184 (quote translated from the original German).

[9] Egils Milbergs, 'Innovation Vital Signs. Framework Report Update.' (2007) 5 <http://innovate.typepad.com/innovation/files/innovation_vital_signs_framework_report_v.2.8.pdf> accessed 14 September 2018.

The European Commission goes on to say:

> What is innovation? There is no one single definition. But innovation as described in the Innovation Union plan broadly means change that speeds up and improves the way we conceive, develop, produce and access new products, industrial processes and services. Changes that create more jobs, improve people's lives and build greener and better societies.[10]

Finally, for the COTEC Foundation for Innovation: 'Innovation is all kinds of change (not only technological) based on knowledge (not only scientific) that generates value (not only economic)'.[11]

As can be seen, innovation definitions start with a focus on the emergence of the innovation, and then increasingly pay attention to societal function fulfilment or environmental impacts. Over time, innovation also starts to include less tangible, non-technical concepts in its output and in some cases, such as recent ones, its value and impact is not limited only to the economy but embraces society as well. Innovation is accelerating because of 'new information/digital applications, ubiquitous communication capabilities, and the international mobility of talent'[12] spurring the collaborative advantage.

Systemness, meaning the systemic character of innovation patterns,[13] is a milestone in an approach that allows for the innovation assessment and boosting that is the objective of the European Union.[14] To define a system,[15] it must be dynamic (constantly changing) and evolving

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[10] European Commission, 'Turning Europe into a True Innovation Union' (Memo/10/473, 2010) 14 1 <http://europa.eu/rapid/press-release_MEMO-10-473_en.htm?locale=en> accessed 14 September 2018.

[11] COTEC Foundation for Innovation <http://cotec.es/quienes-somos/presentacion/> accessed 16 September 2018 (translated from the original Spanish).

[12] Milbergs (n 9) 2.

[13] Loet Leydesdorff, 'The Triple Helix, Quadruple Helix, …, and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy?' (2012) 3(1) Journal of the Knowledge Economy 25. Available at <www.leydesdorff.net/ntuple> accessed 16 September 2018; Jeremy Lent, *The Patterning Instinct: A Cultural History of Humanity's Search for Meaning* (Prometheus Books 2017).

[14] European Commission, '2016 European Innovation Scoreboard' (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs 2016) <https://publications.europa.eu/en/publication-detail/-/publication/6e1bc53d-de12-11e6-ad7c-01aa75ed71a1> accessed 24 September 2018; European Commission, *Innovating for Sustainable Growth: A Bioeconomy for Europe* (Directorate-General for Research and Innovation 2012).

[15] The father of system theory is considered to be Ludwig Von Bertalanffy. Ludwig Von Bertalanffy, *General System Theory*, vol 1 (George Braziller, Inc 1968).the extension of the frameworks to other areas (notably the social sciences.

(having emergent properties),[16] and be more than its parts due to the created synergies. It must be connected to elements, actors, agencies, nodes, stocks or 'parts', and have a boundary, constraints, conditions and principles according to which the system works. Systems are defined by their interrelationships and their functionality or potential. In our complex world,[17] system theory and thinking are crucial to enabling us to understand the world's functioning from a cognitive perspective.[18] 'Culture shapes values and values shape history'.[19] Therefore, it is very important to build an interpretative framework to provide some understanding in the complexity of a 'world transfixed by the dazzle of technology'.

This article will present the perspective of innovations that have the possibility of becoming ecosystem innovations, meaning the kind of innovation that implies the changing of the system itself in a dynamic way. This can be traced back to Schumpeter (mainly through the 'creative destruction' concept) but also to Kondratieff and his 50-year cycles based on the development of a specific innovative technology.[20]

There are several challenges facing bioeconomies, both globally in general and those of the European Union in particular: global warming, social inequality and slow growth.[21] These are the engines for the new innovation fields of our time in the European Union. The free movement of knowledge, technology and researchers, known as the fifth freedom (after goods, people, services and capital) is in this sense a potential EU field of improvement.[22] The European Union is seen here as the location of a

[16] Leyla Acaroglu, 'Tools for Systems Thinkers: Getting into Systems Dynamics… and Bathtubs' (*Disruptive Design* 13 September 2017) <https://medium.com/disruptive-design/tools-for-systems-thinkers-getting-into-systems-dynamics-and-bathtubs-1f961f7c4073> accessed 16 September 2018.

[17] Complex and not only complicated. A system is complicated when it can be completely described by its elements and their relationships. In a complex system, due to the nonlinear relations and feedback loops, it can never be precisely described.

[18] Draper LJ Kauffman, *Systems One: An Introduction to Systems Thinking* (Inc Future Systems ed, TLH Associates 1980); Lent (n 13).

[19] Lent (n 13) 27.

[20] Nikolai D Kondratieff, 'The Long Waves in Economic Life' (1935) 17(6) The Review of Economic Statistics 105; Carlota Pérez, 'Las Revoluciones Tecnológicas Como Grandes Oleadas de Desarrollo Sucesivas', part one in Carlota Pérez, *Revoluciones Tecnológicas y Capital Financiero: la dinámica de las grandes burbujas financieras y las épocas de bonanza* (Siglo XXI 2004).

[21] European Commission, 'The Knowledge Future: Intelligent Policy Choices for Europe 2050' (Directorate-General for Research and Innovation 2015) <https://ec.europa.eu/research/pdf/publications/knowledge_future_2050.pdf> accessed 16 September 2018; European Commission, 'A Journey into 2050 Visions and Policy Challenges' (Digital Futures Final Report 2016) <https://ec.europa.eu/futurium/en/content/digital-futures-final-report-journey-2050-visions-and-policy-challenges> accessed 16 September 2018.

[22] Sara González Fernández and Juan Mascareñas Pérez-Iñigo, 'Una Estrategia de I + D + i Para La Unión Europea: Hacia La Quinta Libertad Básica' [2012] Junio Ciencias de la administración 25.

specific development stage of innovation ecosystems in terms of its general progress level, institutional logics, common specificity of culture, and approach to innovation and change. For instance, in developing countries, certain assumptions would probably not be considered crucial (like inequality in China, process management culture, etc) or other assumptions would need to be taken into account (ownership structure, for example).[23]

The objective of this article is to provide a comprehensive framework[24] to describe and assess the structural advancement related to the maturity of an innovation ecosystem,[25] including actors and processes. This is very important, as in this way a more dynamic perspective can be reached, allowing for the differentiation and highlighting of aspects naturally overshadowed or even overlooked in the more static approach of standard innovation studies. At each level, other actors should have a slightly different role, and be more active and important. They also relate to each other in a different manner. The closer study of intermediary actors[26] emerging in the process (together with the advancing innovation propagation) is another focus point. Their emergence and density are seen as indicators of innovative ecosystem advancement. From the process perspective,[27] the diffusion and use of innovation in static studies understood implicitly, need to be put forward. The feedback loops of learning and adopting innovation have a logical and hierarchical relationship to each other.[28] Thus, there is also a requirement to include the users/participants of the innovation in the equation.[29]

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[23] Yuzhuo Cai, 'Implementing the Triple Helix Model in a Non-Western Context: An Institutional Logics Perspective' (2014) 1 Triple Helix 1 <http://dx.doi.org/10.1186/s40604-014-0001-2> accessed 16 September 2018.

[24] The framework's role allows for appropriately structured data collection and the subsequent analysis of the fundamental indicators of innovation ecosystem advancement and performance.

[25] Frank W Geels, 'Processes and Patterns in Transitions and System Innovations: Refining the Co-Evolutionary Multi-Level Perspective' (2005) 72 Technological Forecasting and Social Change 681; Yuzhuo Cai, 'What Contextual Factors Shape "Innovation in Innovation"? Integration of Insights from the Triple Helix and the Institutional Logics Perspective' (2015) 54(3) Social Science Information 299. Available at <http://journals.sagepub.com/doi/full/10.1177/0539018415583527> accessed 24 September 2018.

[26] Howard Partners, 'Study of the Role of Intermediaries in Support of Innovation' (2007) <www.howardpartners.com.au/assets/innovation-intermediaries-publication-report-apr-2007---final.pdf> accessed 24 September 2018.

[27] Geels (n 25); Juan Mejía-Trejo and José Sánchez-Gutiérrez, 'The Determinant Factors of Innovation Related with Customer Knowledge Management' (2014) 21 Revista Universitaria Europea 133.

[28] Geoff Mulgan, *Big Mind. How Collective Intelligence Can Change Our Word.* (Princeton University Press 2017).

[29] Frank W Geels, 'From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory' (2004) 33 Research Policy 897.

Hopefully, the framework proposed in the following pages will amplify the vision of contemporary innovation ecosystems work and organise an understanding of the way their measurement can evolve, thus deepening the dynamic perspective.

2 Actor definition: triple helix theory

For the purpose of defining an innovation ecosystem, the triple helix is applied as the most comprehensive framework for a definition of the main actors. It was defined first by Lowe, borrowing from the language of DNA cell biology,[30] and further developed by Etzkowitz and Leydesdorff.[31] However, the idea of the triple helix mechanism goes back as far as ancient Mesopotamia and its application in irrigation systems.[32] Increasingly, its concepts are being applied in the policies planned in the European Union and the way they are assessed.[33]

The origins of the triple helix are deeply rooted and can be traced back to the 'triangle' notion defined by Sabato[34] with its government, industry (productive structure) and science (science and technological infrastructure) interaction node, where technology and science are seen as the catalysts for political, economic and social change.

The triple helix, like the double helix of cell DNA, has both structural and functional attributes.[35] Innovation is destabilising and a recombinant of all the elements. The triple helix metaphor also implies the spinning, evolving structure of the elements as the spirals of the helix intertwine.[36]

Following the development of the triple into the quintuple helix theory,[37] one of the aims of this research is an attempt at a slightly different

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30 CU Lowe, 'The Triple Helix: NIH, Industry, and the Academic World' (1982) 55 Yale Journal of Biology and Medicine 239.

31 Henry Etzkowitz and Loet Leydesdorff, 'The Triple Helix---University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development' [1995] EASST Review <www.leydesdorff.net/th1/index.htm> accessed 5 October 2017.

32 Etzkowitz (n 3).

33 European Commission, 'European Innovation Scoreboard 2017' (2017) <https://www.rvo.nl/sites/default/files/2017/06/European_Innovation_Scoreboard_2017.pdf> accessed 16 September 2018.

34 He does not explicitly claim the originality of the concept but builds on the flow concept of Jorge Sábato and Natalio Botana [1970] 'La Ciencia y La Tecnología En El Desarrollo Futuro de América Latina' (Instituto de Estudios Peruanos) 15 <http://docs.politicascti.net/documents/Teoricos/Sabato_Botana.pdf > accessed 24 September 2018.

35 Lowe (n 30).

36 Etzkowitz (n 3).

37 Elias G Carayannis and David FJ Campbell, 'Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate to Each Other?'

arrangement of the elements, reframing the triple helix of university/academia, government, and enterprise/industry by considering the additional dimensions of society and the environment.[38] As far as system feedback loops are concerned, just as intracellular feedback modulates the DNA function, so there is a need to balance the elements in order to grow the appropriate structures of society to allow a balanced coexistence with the (natural) environment.

2.1 Innovation helix elements and their basic role

The different elements of the helix are described below, also outlining their basic functions, which change according to the distinct levels of configuration. 'The triple helix is a platform for "institution formation", the creation of new organizational formats to promote innovation, as a synthesis of elements of the triple helix'.[39]

In some way, the three helixes correspond to the knowledge, production and regulatory functions for civil society within a particular, defined location.

The government is the 'source of contractual relations that guarantee stable interactions and exchange'.[40] More specifically, its role encompasses the set of institutional roles that through legislation and the administration formulates policies and directs resources to other vertices.[41] The government is 'the ultimate guarantor of societal rules of the game'.[42] In particular, in the laissez-faire model (described below) 'the role of government is expected to be limited to clear cases of so-called "market failure", when economic impetuses by themselves do not call an activity into existence'.[43]

(2010) 1 International Journal of Social Ecology and Sustainable Development 41; Elias G Carayannis, Thorsten D Barth and David FJ Campbell, 'The Quintuple Helix Innovation Model: Global Warming as a Challenge and Driver for Innovation' (2012) 1 Journal of Innovation and Entrepreneurship 2 <www.innovation-entrepreneurship.com/content/1/1/2> accessed 16 September 2018; Elias G Carayannis and David FJ Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (2014) 3 Journal of Innovation and Entrepreneurship 12 <http://innovation-entrepreneurship.springeropen.com/articles/10.1186/s13731-014-0012-2> accessed 16 September 2018.

[38] 'Institutions are considered as forming the structural underpinning for the helix dimensions. They are considered as playing a role in dynamic innovation developments, rather than explaining inertia and stability', Geels (n 29) 3.

[39] Etzkowitz (n 3) 31.

[40] Etzkowitz (n 3) 22.

[41] Sábato and Botana (n 34).

[42] Etzkowitz (n 3).

[43] Etzkowitz (n 3) 29.

Besides being important in macroeconomic factors, such as market access policies, regulations, standards, fiscal and monetary environment, taxes, interest rates, and public policy conditions for R&D funding policy and intellectual property, the government is also responsible for infrastructure conditions that are especially relevant for innovation, such as IT infrastructure or the quality of physical infrastructure.[44]

Industry is the primary base of productive activities, as it provides goods and services for society. Back in the 1970s,[45] the main responsibility of industry was to assure profits, which is still valid in the mind of the public today. In order to perform this role, industry 'needs public infrastructure - not only physical infrastructure like highways and airports, but also social infrastructure like good schools, safe neighborhoods, and effective legal systems'.[46]

University and other knowledge-managing institutions collectively known as academia perform the role of education (the preservation and transmission of knowledge) and research (both basic and applied) but also cultural memory. The socialisation of youth and dissemination of knowledge are also important core functions.

The roles of society and the (natural) environment are not considered in the basic stages of innovation ecosystem development mainly because in the increased complexity of the actual world arrangement their role is understood as the arena for the actions of other helixes.

2.2 Innovation helix configuration stages

Triple Helix theory counts 3 levels of configuration: the first two being somewhat introductory arrangements for the real dynamics of the innovation helix.[47]

The very first stage of configuration is called the statist model, where the nation state, represented by the government, embraces academia and industry and governs relations between them. This situation was represented by the ex-communist states' modus operandi and, according to some, probably in all countries all over the world before, during and immediately after national emergencies, especially after World War

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[44] Milbergs (n 9) 11.

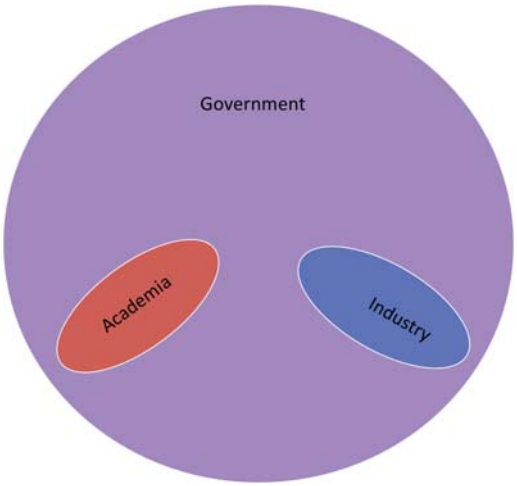
[45] Following Milton Friedman or Simons.

[46] Laura D'Andrea Tyson, 'What Role Should Business Play in Society?' (*World Economic Forum* 6 November 2013) <www.weforum.org/agenda/2013/11/what-role-should-businesses-play-in-society/> accessed 16 September 2018.

[47] Henry Etzkowitz and Loet Leydesdorff, 'The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University – Industry – Government Relations' (2000) 29 Research Policy 109.

II.[48] Horizontal collaboration between academia and industry in this very first stage can mainly be realised through human resource transference between these two vertices.[49] Specialised basic and applied research institutes, together with sectoral units for particular industries, are characteristic of this model.[50]

Figure 1: The academia-government-industry arrangement: the statist model.[51]



The former Soviet Union, France, and many Latin American countries could, historically, partially at least, exemplify the statist model of societal organisation.[52] 'Bureaucratic coordination concentrates initiative at the top and tends to suppress ideas that arise from below'.[53] Thus, this model functions sub-optimally for the requirements of the knowledge society.

The second stage of configuration is called laissez-faire and is represented by relatively independent institutional spheres having strong borders dividing them and highly circumscribed relations among the spheres.[54] The actors interact only modestly across strong boundaries. The driving force in this configuration is industry, as opposed to the gov-

48 Lowe (n 30); Sábato and Botana (n 34); Etzkowitz (n 3).

49 Sábato and Botana (n 34).

50 Etzkowitz (n 3) 27.

51 Based on Etzkowitz and Leydesdorff (n 47).

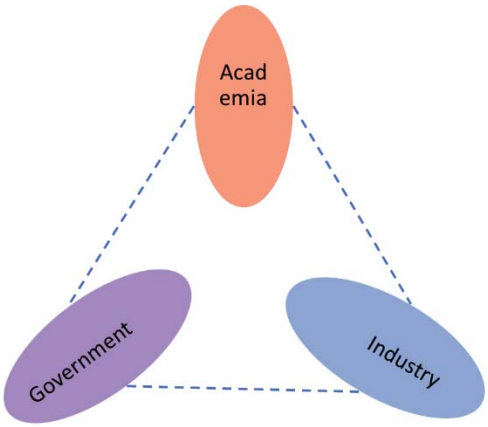
52 Etzkowitz (n 3).

53 Etzkowitz (n 3) 15.

54 Etzkowitz and Leydesdorff (n 47) 111.

ernment in the statist model.[55] Collaboration is forbidden at the very first stage to avoid cartel practices in industry. Afterwards, however, strategic alliances are allowed and also competition as a mix between rivalry and cooperation and collaboration.

Figure 2: The academia-government-industry arrangement: the laissez-faire model.[56]



This was the perceived situation in the USA and also in Sweden.[57] However, although the government financed public universities, the allocation of financing always corresponded to its own requirements when it came to translating society's desires for knowledge, even taking into account the underpinning 'intellectual freedom' in basic research.[58] Furthermore, the strong impulse to finance innovation provided by military investment by the US government, especially in relation to World War II, which resulted in, among other things, Silicon Valley, where start-ups were initially offshoots of military programmes, is evidence of the existence of such a state more in the public imagination than in reality.[59]

Actors at this stage are supposed to communicate through intermediary organisations in order to maintain the purity of institutional spheres.

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55 Etzkowitz (n 3).

56 Based on Etzkowitz and Leydesdorff (n 47).

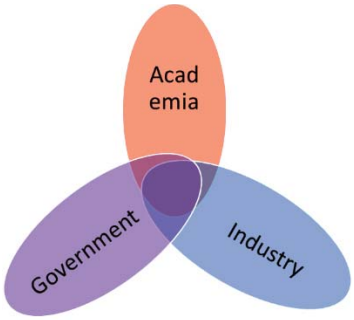
57 Cai (n 25); Henry Etzkowitz, 'The Triple Helix of University-Industry-Government: Implications for Policy and Evaluation' (2002) 11 Working Paper 1/2002 <http://www.sister.nu/pdf/wp_11.pdf> accessed 16 September 2018.

58 Lowe (n 30).

59 Sábato and Botana (n 34).

The third stage of configuration is called the triple helix balanced model, and characterises the knowledge society as an evolved version of the industrial one. It generates 'a knowledge infrastructure in terms of overlapping'[60] between the three agencies, as shown in the figure below. It will be described in detail in the next section.

Figure 3: The academia-government-industry arrangement: the triple helix model.[61]



2.3 The balanced innovation helix and its levels of configuration

The triple helix theory can be extended algorithmically into n-tuple helices[62] to include civil society as a strand[63] and the glocal (global and local)[64] dimension of the helix. According to Etzkowitz,[65] effective interaction indeed requires the participation of civil society. However, it is considered as one type of institutional logic supporting the ideal triple helix model rather than as an additional helix. We support this assumption, because the three strands are already part of society and, together with consideration of the environment, need to be asserted in the innovation helix arrangement of the contemporary world in general and the European Union in particular.

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[60] Etzkowitz and Leydesdorff (n 47) 111.

[61] Etzkowitz and Leydesdorff (n 47).

[62] Leydesdorff (n 13); Han Woo Park, 'Transition from the Triple Helix to N-Tuple Helices? An Interview with Elias G Carayannis and David FJ Campbell' (2014) 99 Scientometrics 203.

[63] Elias G Carayannis and David FJ Campbell, *Mode 3 Knowledge Production in Quadruple Helix Innovation Systems* (Springer 2012); Carayannis and Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (n 37).

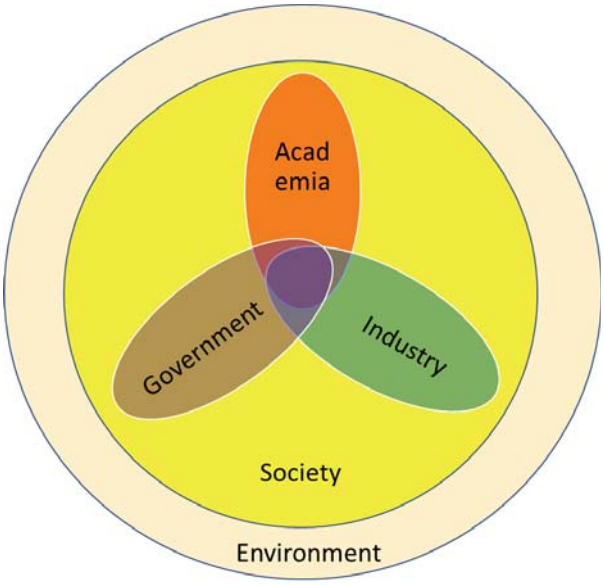
[64] The glocal dimension is not to be confused with the glocalisation concept, which is mainly a marketing tool when international products are adapted to the particularities of the local culture where they are sold.

[65] Etzkowitz (n 3).

The local dimension reclaims the central position of cities and regions (even more so neighbourhood-level micro-clusters) in the process of innovation and entrepreneurship, positing them as the central organising unit for these processes which mainstream economic theory places mainly at the level of the firm, entrepreneur or national economy.

Creativity, innovation and entrepreneurship are considered social processes that involve diverse groups of people and assets that build off one another historically. They do not simply take place in cities or regions but in fact require them. In cities and regions, scope and diversity trump the scale and specialisation of industrial societies.[66] These outcomes lead to the figure shown below.

Figure 4: The triple helix reframed.



Source: own diagram based on the triple/quintuple helix model.

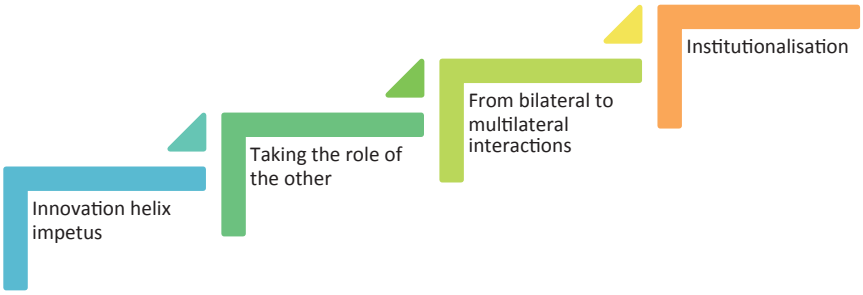
There are several phases in the development of the innovation helix balanced model, distinguishing and modifying it accordingly:[67] the 'innovation helix impetus'; 'taking the role of the other'; 'from bilateral to multilateral interactions'; 'institutionalisation of the innovation helix'.[68]

[66] Richard Florida, Patrick Adler and Charlotta Mellander, 'The City as Innovation Machine' (2017) 51 Regional Studies 86.

[67] Etzkowitz (n 3).

[68] Cai (n 25).

Figure 5: Levels of configuration of the balanced innovation helix.[69]



The innovation helix impetus stage takes place as academia, industry, and government enter into a reciprocal relationship with each other in various combinations in which each attempts to enhance the performance of the other but from the perspective of the traditional role of each of the strands.[70] These activities are mainly based on and aimed at the regional level as part of industrial cluster development dynamics. However, at this stage, the economy base shifts toward intellectual capital and knowledge capitalisation, and academia becomes the driving force of progress. We argue that society and the environment are increasingly an important point of consideration at this stage, because only societal involvement and consideration of the environment can lead to support for this dynamic, giving it the necessary force.

The 'taking the role of the other' stage[71] means the internal transformation of the helix strands in which, in addition to performing their traditional tasks, they assume additional ones to improve innovation process functioning.

Academia starts to become involved in industrial activities mainly through patents. It also becomes a source of venture capital, involving itself in incubating activity and spin-off company creation in addition to its traditional role of education and research. These latter can also be modified to include new programmes supporting this new focus.

In the industrial sector, companies start to give training at higher levels and establish their own laboratories, research centres or even 'universities'.

The government or governmental agencies provide support mainly through venture capital, meaning capital for innovative start-ups.

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69 Own diagram based on Etzkowitz (n 3); Cai (n 25).

70 Etzkowitz (n 3) 21.

71 Etzkowitz (n 3) 22.

Society becomes involved in the processes of industry through prosumer roles. The government starts to include deliberation and citizen participation axes in their decisioning processes, while academia involves the local and cognitive knowledge of citizens in their research.

Environmental considerations at this stage should already be the basis of all agents' actions.

A meta-innovation system is developed[72] when the helixes' interactions evolve from the bilateral to tri- or even multilateral. An intersection of communications, networks, hubs and organisations among the helixes should appear in this model. Multilateral interactions[73] suppose more interoperability inside the helix configuration, and cooperation evolves so that one sphere's actions affect the other sphere. However, they maintain their core identities. Here is where collective intelligence[74] starts to take root in the innovation ecosystem.

The interactions also result in the proliferation of hybrid, intermediary entities, such as incubators/accelerators, joint research centres, and science or technology parks.[75]

University assumes an entrepreneurial role, training not only individuals but also organisations in incubators developing new products. Entrepreneurship becomes fully integrated in teaching and research functions. Consultation with industry is included in the role of universities, and liaison offices are created to identify appropriate industrial partners and allow smooth relationships to function. In addition, third-party intermediary organisations are hired to enable intellectual property transfer. Participative science through mass data gathering and deliberative processes for 'wicked' questions starts to be considered as one of the pillars of scientific proceedings.

'Learning by borrowing'[76] is also associated with this stage of the process, importing and adapting organisational models from abroad, as

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[72] Etzkowitz (n 3).

[73] 'An interaction of two parties may become stuck, either in hyper-agreement or in excessive conflict, resulting in divorce. A third factor allows a dispassionate element to be introduced into the relationship, mediating, and potentially reducing, the tendency to overidentification on the one hand and escalation of divisiveness on the other', Georg Simmel, *The Sociology* (The Free Press 1950).

[74] The term 'collective intelligence' with its basic meaning of the team having more wisdom than the individual can be traced back as far as Aristotle. However, the conception of the 'noosphere' as the world brain is attributed to Vladimir Vernadsky and Teilhard George S Levit, 'The Biosphere and Noosphere Theories of VI Vernadsky and P Teilhard de Chardin: A Methodological Essay' (2000) 50 Archives Internationales d'histoire des Sciences 160.

[75] Cai (n 25) 10.

[76] Etzkowitz (n 3) 21.

well as independent inventions. An example is the import of hybrid, intermediary organisations.

Following Cai[77] and the process approach developed below, we assume that there is another step in the development of the helix model involving the institutionalisation of the innovation helix concept and its associated activities when they have become 'a set of routines or practices that are reproduced over time and tend to serve as a cognitive framework structuring the actions of key actors'. The formal structures need the support of the organic development of values and attitudes that allow for the implementation of designed processes and relations.[78] From the multilevel perspective, this would mean transfer from the regime to landscape level through feedback loops and democratic process involvement.[79]

3 The multilevel innovation process perspective

The innovation process is depicted by applying the multilevel perspective. This was inspired by Rip and Kemp[80] and further developed by Frank Geels,[81] and has three levels: niches, socio-technical regimes and landscapes.

This typology is based on the rules which guide actors by providing stability and directing perceptions and actions. Because rules tend to be reproduced, they are characterised as the deep structure or grammar of sociotechnical (ST) systems.[82] As shown in the pyramid of rules in Figure 6, there are three types of rules.

Cognitive rules are the foundation of the nature of reality and the frames of reference through which meaning or sense is established. Symbols like words, concepts, myths, signs or gestures exert their effect by shaping the meanings we attribute to objects and activities.[83] Cognitive rules embody shared belief systems and expectations, which direct

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[77] Cai (n 25) 13.

[78] Sábato and Botana (n 34).

[79] 'There also enters the three level of rules mechanism, meaning regulative, normative and also cognitive ones', Cai (n 25).

[80] Arie Rip and René Kemp, 'Technological Change' (1998) 2 Human Choice and Climate Change 327.

[81] Frank W Geels, 'Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study' (2002) 31(8-9) Research Policy 1257 <http://www.sciencedirect.com/science/article/pii/S0048733302000628> accessed 16 September 2018.

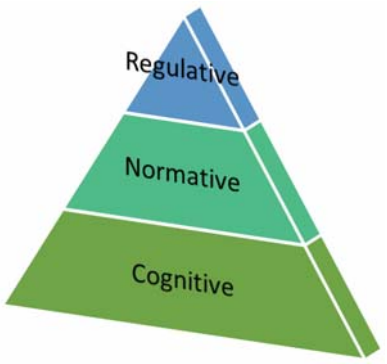
[82] Geels (n 29) 910.

[83] Geels (n 29).

history[84] but also orientate perceptions of the future, and therefore steer actions in the present.[85] As one way of viewing things is established, it makes participants 'blind' to another way.

Normative rules have been emphasised by traditional sociologists, starting from Simmel.[86] These rules confer values, norms, role expectations, duties, rights, and responsibilities.[87] Sociologists argue that such rules are internalised as implicit beliefs through socialisation processes. Social and organisational networks are stabilised by mutual role perceptions and expectations of what is seen as proper behaviour. There is, however, a two-way relationship or a bidirectional feedback loop between history or the tangible world and cognition during their evolution.[88]

Figure 6: Pyramid of rules.



Source: own diagram.

The regulative dimension is made up of explicit, formal rules, which constrain behaviour and regulate interactions, ie government regulations which structure the economic process.[89] Here, rewards and punishments are backed up with sanctions (eg the police and courts). Institutional economists tend to highlight these formal and regulative rules.[90]

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84 Lent (n 13).

85 Geels (n 29) 910.

86 Simmel (n 73).

87 Geels (n 29) 904.

88 Lent (n 13).

89 Geels (n 29) 904.

90 Geels (n 29).

Alignment between rules is an important element of the stability of the systems and regimes built upon them. The more we progress in the pyramid, the more socially controllable and changeable the rules are. Regimes are formed by the social structuring of these rules. For the different multi-perspective levels, more rules are in force and action is more stable and structured as we progress from niches, through regimes into landscapes. The term 'institutional logics' generally refers to the broad categories of beliefs and motive systems that shape the cognition and behaviour of actors.[91]

Niches constitute the micro-level where radical innovations are conceived and developed in their early stages. Niches are more radical, as they deviate from more rules.[92] Thus, there is more space available for them to go in different directions in search of variety, even if in some dimensions they stick to existing rules.[93] Niches try to address sociotechnical regime and landscape issues.

Sociotechnical regimes imply a technological trajectory and pattern the way technology is applied in the economy and society. However, core capabilities can become 'core rigidities'. 'Learning is cumulative in the sense that it builds upon existing knowledge and refines it. Competencies, skills, knowledge also represent a kind of "cognitive capital" with sunk investments'.[94] The same is true for the existing infrastructure: physical (associated with 'hardness') but also organisational or legal. 'Powerful incumbent actors may try to suppress innovations through market control or political lobbying. Complementarities between components and sub-systems are an important source of inertia in complex technologies and systems'.[95] The lifestyles of people are dependent on the existing status quo.

The sociotechnical landscape constitutes 'an exogenous environment beyond the direct influence of niche and regime actors (macro-economics, deep cultural patterns, macro-political developments, already existing infrastructure, the natural environment)'.[96] In a more utilitarian

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[91] Roger Friedland and Robert R Alford, 'Bringing Society Back In: Symbols, Practices, and Institutional Contradictions' in Walter W Powell and Paul J DiMaggio (eds) *The New Institutionalism and Organizational Analysis* (University of Chicago University Press 1991) 252.

[92] GPJ Verbong and Frank W Geels, 'Exploring Sustainability Transitions in the Electricity Sector with Socio-Technical Pathways' (2010) 77 Technological Forecasting and Social Change 1214 <http://linkinghub.elsevier.com/retrieve/pii/S0040162510000752> accessed 5 October 2017.

[93] Geels (n 29) 912.

[94] Geels (n 29) 910; Mulgan (n 28).

[95] Geels (n 29) 911.

[96] Frank W Geels and Johan Schot, 'Typology of Sociotechnical Transition Pathways' (2007) 36 Research Policy 399, 410.

way, it can also have the characteristics of a 'national mindset'.[97] The sociotechnical landscape would need to provide the instruments for the external accountability structure for the actors, their disciplining, and the eliciting of correct information, thus avoiding the trap of the revelation principle.[98] It should also lead to avoiding sub-optimal innovation ecosystem lock-ins for considerable periods of time.[99] Leydesdorff proposes the overcoming of the problem through the actors' 'differentiation and integration'.[100] The external accountability structure and bottom-up learning processes with their loops[101] should avoid 'reification of systems (or states and interstate dependency-relations) as barriers to innovation'.[102]

From the collective intelligence perspective, groups encounter 'triggered hierarchies', many questions are automated, and only when they encounter difficulties are higher levels of hierarchy called, bringing additional resources, power and knowledge. Three learning loops can be distinguished:[103] adopting ideas, thoughts and actions within a given paradigm, then in certain situations (when the difficulty encountered requires it and collective intelligence works) the second loop is called for and changes or creates new categories and models to think with, while in a further set of situations associated with the third loop, there is a redesigning of the very framework for conceiving knowledge or rethinking how to think.[104] Organisational hierarchies often struggle to operationalise all three loops because the latter two are likely to threaten the status of leaders or experts.

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97 Milbergs (n 9).

98 Herbert Gintis, 'Why Schumpeter Got it Wrong in Capitalism, Socialism, and Democracy' [1990] Challenge Magazine 1 <http://www.umass.edu/preferen/gintis/SchumpeterChallenge.pdf> accessed 17 September 2018.

99 Geels (n 29).

100 Loet Leydesdorff, 'The Triple Helix of University-Industry-Government Relations' [2012] Scientometrics 14.

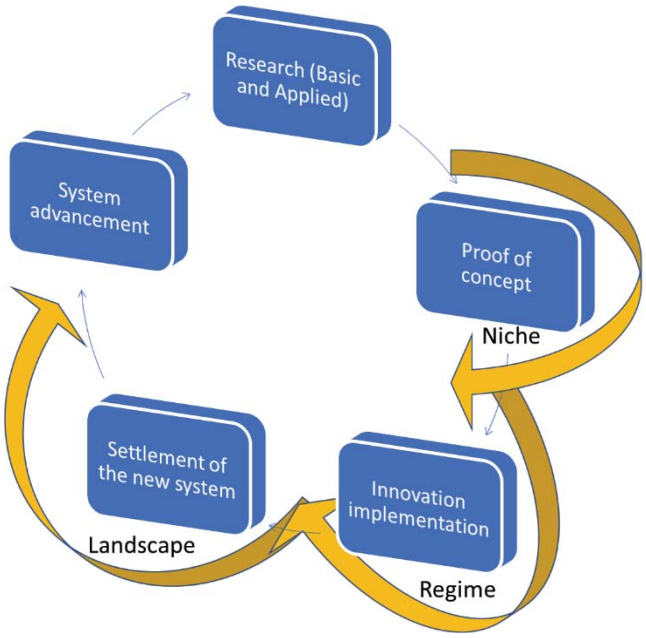
101 Mulgan (n 28).

102 Leydesdorff (n 100) 2.

103 Mulgan (n 28).

104 Sometimes when the answer to the question cannot be found, there is a need to change the question itself.

Figure 7: MLP-based innovation loop.



Source: own diagram based on MLP.

4 Matching MLP with the reframed triple helix

Both perspectives have been carefully matched to allow the study of a determined innovation ecosystem, as previously announced, from the advancement[105] point of view. This includes the process perspective but also the institutional one, involving the roles undertaken by each of the actors (as shown in the reframed triple helix perspective), the way they relate to each other, and the development of intermediary entities.

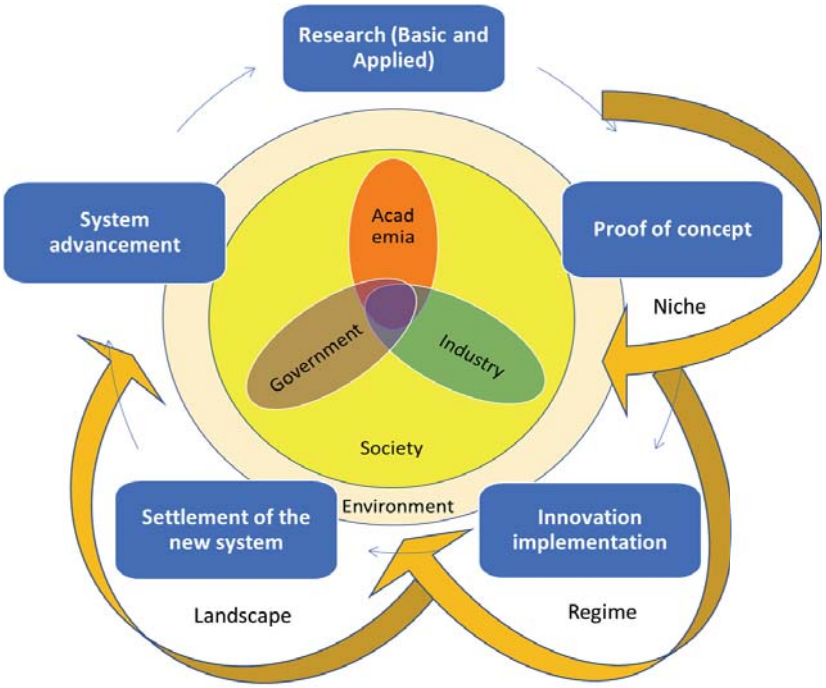
From the multilevel perspective, a typology of four transition pathways:[106] transformation, reconfiguration, technological substitution, and de-alignment and re-alignment is proposed. These pathways display differentiated combinations of the timing and nature of multilevel interactions. This approach is centred on sociotechnical regimes, technical regimes and the related 'technological trajectories' first described by Nel-

[105] Geels (n 25); Cai (n 23).

[106] Geels and Schot (n 96).

son and Winter[107] and enriched with a broader sociological perspective by Bijker.[108]

Figure 8: Innovation loop with the actors involved.



Source: own diagram based on the triple helix and MLP.

The multilevel perspective says that system transitions take place due to the interactions between the processes at the three levels shown in the figure above. The innovation needs to be discovered and translated into practice, and a proof-of-concept needs to be run. After this building of internal momentum, through learning processes, further price/performance improvements, and support from powerful groups which have joined in the process (which is also very important), changes at the landscape level start increasing pressure on the regime, and destabilisation of the regime creates windows of opportunity for niche-innovations

[107] Richard R Nelson and Sidney G Winter, *An Evolutionary Theory of Economic Change*, vol 93 (Harvard University Press 1982).

[108] Wiebe Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (MIT Press 1997).

to appear.[109] It can also lead to an understanding of the 'valley of death'[110] casuistic, which is one of the main problems to overcome for promising novelties and ideas to become real world innovations.[111] For some, the main question here is translational research funding and its operationalisation through firm incubations, which is understood as the move of an idea past the basic discovery stage towards and through prototyping, proof-of-concept tests and scale-ups to implementation.[112]

Creative industry schema add another step to this process, ie 'adoption and adaptation of a novel product or service to human lifestyles, along with its retention and normalization by a population of carriers'.[113] These adoption process also needs to occur in social markets.[114]

Probably, this process point of view would lead to the following linear/loop sequence: the innovation process would start with society at the landscape level, which requires changes through governmental pressure, the government provides universities with the impulse to work on solution development, and industry allows for its implementation and propagation. This loop would lead to society evolution, restructuring needs, and allowing for another loop.

This process perspective can also be seen in the panarchy scheme. However, this is related more to natural ecosystems, ie ecological and socioecological ones. There are four phases described: 'exploitation'; 'conservation'; 'release' or 'creative destruction', a term derived from Schumpeter;[115] and 'reorganisation'.[116]

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109 Geels and Schot (n 96) 400.

110 Jackson (n 4); Thomas W Peterson, 'The Role of the National Science Foundation in the Innovation Ecosystem' (NSF Directorate of Engineering 2010) <https://www.nsf.gov/eng/iip/innovation.pdf> accessed 17 September 2018.

111 Frank W Geels, 'Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective' (2010) 39 Research Policy 495 <http://dx.doi.org/10.1016/j.respol.2010.01.022> accessed 17 September 2018.

112 Peterson (n 110).

113 J Potts, 'Art and Innovation: An Evolutionary View of the Creative Industries' [2007] ARC Centre of Excellence for Creative Industries 1, 6; Carayannis and Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (n 37).

114 Potts (n 113).

115 Schumpeter (n 8).

116 Nicholas M Gotts, 'Resilience, Panarchy, and World-Systems Analysis' (2007) 12 Ecology and Society.

5 Hybrid, intermediary organisations in the innovation helix

A very important aspect is not only the appearance or existence of an organisation but also the density of the innovation space regarding different actors and their interactions. Only in this way can an innovation ecosystem become a self-sustaining regenerative source of economic and social development. Early-stage innovative activities in particular thrive under agglomeration.[117] Research, design, testing, and even the manufacture of new products and technologies demand environments where all actors congregate together. As these products become mature, however, the benefits of co-location are probably not so relevant anymore.[118]

Below, there is a brief description of the hybrid intermediary organisation which characterises more mature innovation ecosystems. Their number (density), composition and outreach are considered to be indicative of the advancement of the innovation ecosystem.

Science Parks, also referred to as technopolises, in the first place are locations for large firms to situate R&D units, and in the second place ways to collaborate with academic researchers and recruit promising students. Science parks are currently being reformulated as multipurpose entities. These include newly organised universities, research centres with liaison offices, technology transfer offices serving as integrators of triple helix actors through intellectual property transfer, or clusters focused on particular themes. In addition, science parks serve as a receiving point for newly generated successful firms and may also establish an incubator facility to start new companies.[119] Recently, it has been seen that a suburban-style scientific park is not a very good location for start-ups, which prefer urban locations with their diversity and thus creative potential.

Technology transfer offices, which can be traced back to the early 20th century, are thought to expand the field of research into spheres more applicable to industry. Supporting early innovation stages can help researchers identify additional resources to explore the practical implications of their findings, give students and graduates the idea of how to recognise a patentable invention, identify the possibility of the commercialisation of the research and also support 'the proof of concept' phase of research application, and finally disseminate knowledge through the publication and expansion of research, which also results in 'advertising' to potential licensees. The ability to file provisional patents is reduced

117 Florida, Adler and Mellander (n 66).

118 Florida, Adler and Mellander (n 66).

119 Etzkowitz (n 3).

quickly if the potential conflict between publication and patenting is not eliminated.[120, 121] There can also be centres for cross-border technology transfer like IRC:[122] the Innovation Relay Centres Network. Consulting offices with looser relationships to academia are another kind of intermediary organisation in the innovation process.

Academia can also arrange multidisciplinary centres in order to attract greater amounts of funding and allow for large-scale project implementation, together with new physical facilities or expensive research instrumentation. A centre can also be a succession of strategic alliances to achieve a longer-term goal in regional development.

Accelerators, incubators and so-called company builders are the next hybrid actor to consider in the further stages of innovation progress in start-up company advancement.

Incubators are usually 'physical spaces attached to a knowledge centre (university, research institute, business school, etc) to help commercialise its own start-ups and foster business ideas from its network in exchange for a monthly rental fee'.[123] Incubators were initially established to speed up knowledge flow and technology transfer from universities to industry. The early origins of incubators and also technology transfer offices can be traced back to Edison's 'Invention Factory' founded in the late 19th century, which tried to systematise the invention and commercialisation of technology. A similar model can currently be seen in private/networked incubators developed around certain technology and working on a common business model of firm formation. As they also supply capital, they can be related to the venture capital firms started in the early post-war period, which are the second source of incubation activities. The third one would be an extension of corporate R&D or development labs. When technology was not core to a corporate business, it was given ways to develop through so-called 'skunkworks'. Sometimes internal corporate incubators were established, too. They could be considered as some kind of test, as corporate employees could venture into a new activity and come back to the corporation if it was not successful, and the company could share its costs in attracting new investors but retain the rights (to purchase) if the spin-off developed favourably. Xerox

120 As exclusive licences and patentable inventions become the goal of university laboratories, secrecy can start to be an issue, and even the peer review system is challenged (as it is not paid, many times not efficiently run, and also external to universities).

121 Etzkowitz (n 3).

122 'Innovation Relay Centre Network', European Industrial Research Management Association <https://www.eirma.org/node/69242> accessed 17 September 2018.

123 Eduardo Salido, Marc Sabas and Pedro Freixas, 'The Accelerator and Incubator Ecosystem in Europe' (Telefonica 2013) 9.

even recognised them as profit centres. They are very prone to disappearing during crises and reappearing in more prosperous times. Their essential purpose is to teach a group of people to act as an organisation.

The field of incubators originally created at MIT has also started to be developed by industry and non-governmental organisations (NGOs), these latter organising cooperatives to help the poor, possibly in depressed areas. In addition, associations of incubators can also evolve in order to perform special missions. Finally, different government levels also become involved in incubation activities. Beyond firm-formation, incubation is part of a broader framework for filling gaps in clusters, increasing the organisational density of regions, and introducing new organisational capabilities into society.[124]

Accelerators generally imply an application process which is open to all, and a pre-seed investment is exchanged for a minority stake in the start-up. Support is limited in time and includes events and also intensive coaching and mentoring, while the programme itself is organised in sets or groups of start-ups beginning at the same time.[125] This began with Y-combinator in the US.

In a company builder / start-up support model, new business opportunities are usually sourced from the know-how of the company builder/ founder in an area or sector. The main characteristics are: 'work through market validation before putting a team together, almost full ownership of the start-up and bootstrapping during initial phases using the founder's resources'.[126] It is typical of the Berlin area.

There are many other kinds of initiatives that encourage entrepreneurship and start-up progress, but most are 'either focused on broader areas of incidence or on a particular aspect of entrepreneurship'.[127] A general trend towards greater specialisation within the acceleration and incubation sectors can be distinguished.

Venture capital is the third important intermediary actor to appear in the more mature innovation ecosystem. It is supposed to be much more than a financial investment mechanism or instrument, and an engine of regional renewal. Its original idea was to provide the funds for early stage innovations. However, private venture capital companies, in particular at later stages in the venture capital cycle,[128] try to minimise risk and maximise profits in the very short-run, and become more fo-

[124] Etzkowitz (n 3).

[125] Salido, Sabas and Freixas (n 123) 9.

[126] Salido, Sabas and Freixas (n 123) 9.

[127] Salido, Sabas and Freixas (n 123) 9.

[128] Etzkowitz (n 3).

cused on the later stages of innovative companies' development. There is a downstream drift, because private capital tends to accentuate the business cycle and herd effect, making it a secondary rather than primary mover due to an increasingly conservative approach and the financing of second-stage imitators with minor variations rather than the originators of a business concept, as these weigh heavily on private venture capital firms.[129] Extreme short-term growth can also be antagonistic to long-term company performance.

Public venture capital, even if veiled or underground in especially liberal economies, can actually be involved in earlier stages by providing seed capital for basic research and therefore offering more opportunities to promote discontinuous innovation and being more stable across business cycles. Optimally, public and private venture capital should be complementary with a growing number of universities also starting to act, so the organisation that is at the origin of the technology has a better chance of taking part in the value that is created, which is not so in the case of intermediary organisations. However, university venture capital must be treated with caution so that it is not diverted excessively to support the projects of influential faculty members.

Individual angels or angel syndicates can also be suitable for filling the gap as venture capital becomes increasingly concentrated in areas with significant knowledge and financial strength in high-growth fields with extraordinary profits in the later stage of the innovation process. These are mainly successful individuals who take this as an alternative option to retirement and to stay 'in the game'.[130] Angels are willing to assume greater risk, are less volatile especially in economic downturns and can also provide new ventures with business and technical expertise. The likelihood of an angel investment is especially higher compared to private venture capital.

Government and academia (also foundation) venture capital is steadier in nature and can provide the capital to overcome the business cycle (countercyclical) and for the earlier stages of innovation venture formation. Their partnering can provide a funding source for less-favoured fields and less venture-capital-intensive regions. It focuses more on the creation of new industries and jobs, seeking long-term economic growth.

An innovative way of financing can be provided through crowdfunding, or going further into the innovation chain, Initial Coin Offerings

[129] Etzkowitz (n 3).

[130] Etzkowitz (n 3).

(ICOs).[131] This last one is a type of crowdfunding that allows investors to buy participation in the company through tokens which have an exchange value within the business model backed up by a blockchain. The value of the token, understood in this way as the presale of company services, is upgraded according to the business expectations of the start-up. Furthermore, tokens can be exchanged on the market applying a minimum conversion rate checked out through the blockchain system.[132]

For leveraging different actors' involvement, innovation hubs[133] for stimulating and articulating innovation networks and clusters[134] are the embryo of innovation ecosystems. Government (especially municipal, although it can be local or regional) and society put in place innovation, living, media, eco or social labs.[135] These labs can be used for the experimental design of big processes, and as sandboxes to check for experimental legislation.

6 Innovation helix elements with their meta-innovation roles

In advanced innovation ecosystem processes, the traditional roles of the actors are transformed. All actors need to join their efforts in research support, especially applied and translational, and in firm formation and support to bring ideas onto the market and allow their spreading and the constitution of the new sociotechnical regime and landscape. This spreading can be done with society, especially via the participative and deliberative approach. At all process stages, the environment should be carefully considered.

Another significant factor in innovation ecosystem advancement has its roots in the existence of 'slack' in the culture, which 'permits a divergence from established patterns and activity which is not merely devoted to reproducing the existing society but is aspiring to change it'.[136] This slack can be produced by the introduction and promotion of lateral and vertical expertise mobility from one social sphere to another, as it

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131 Finnovating News, 'Actualidad y tendencias del mercado ICOs 2018' (2018) <http://spanishfintech.net/hacia-nuevo-mercado-intercambio-tokens/> accessed 18 September 2018.

132 Finnovating News (n 131).

133 European Commission, 'Pan-European Network of Digital Innovation Hubs' (2016) <https://ec.europa.eu/digital-single-market/en/digital-innovation-hubs> accessed 18 September 2018.

134 Howard Partners (n 26).

135 Bastiaan Baccarne and others, 'Governing Quintuple Helix Innovation: Urban Living Labs and Socio-Ecological Entrepreneurship' (2016) 6 Technology Innovation Management Review 22.

136 Boulding (n 7) 6.

can stimulate collective intelligence emergence[137] through the hybridisation, invention, and innovation of new social formats, allowing institutional cross-fertilisation.[138] This is related to the geocultural assets of the society and their state of the art as the arena for the communication and transformation, reactivation and recomposition of the public democratic sphere. Here, narrative and productive diversity is the key to the development, social cohesion, resilience and democratic participation of society.[139] Thus, one of the strategic innovative knowledge transmitters across levels is the creative industries or arts,[140] together with design, which bring to the table not only the stimuli for idea creation but also its propagation in regimes and incorporation into the sociotechnical landscape. However, similarly to academia, their contribution is mainly dynamic and thus overseen in the static pictures of standard innovation approaches.

The role of academia is especially relevant in education and basic or blue-sky research, as in the case of research it seems to be the only actor able to perform it with decisive public support. Science is and should become increasingly multi- or inter- or even trans-disciplinary and multi- or inter- or even trans-organisational. In this sense, the involvement of the arts and artistic research is crucial.[141]

As has already been seen, in the more advanced stages of innovation ecosystem development, academia also has the role of 'wealth creation'[142] through the capitalisation of knowledge, which in principle is the main role of industry.[143] The industrial implication in university research support is deemed to be complementary to public spending[144] and should not

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137 Mulgan (n 28).

138 Etzkowitz (n 3).

139 Fundación Alternativas, 'Informe Sobre El Estado de La Cultura En España 2017. Igualdad y Diversidad En La Era Digital' (2017) <http://www.fundacionalternativas.org/public/storage/publicaciones_archivos/6cd717bd9f96c0d102a67139fa3ea3ac.pdf> accessed 19 September 2018.

140 Potts (n 113); Carayannis and Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (n 37).

141 Peterson (n 110); Carayannis and Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (n 37).Tassey 2009

142 As universities become increasingly entrepreneurial, the figure of professor-of-practice (PoP) appears, which means individuals performing dual roles: at the university and in industry. In such a case, conflicts of interest coexist with confluences of interest, or as some state: 'no conflict, no interest' Etzkowitz (n 3). Strategies for dealing with conflicts include publicly stating dual affiliations and removing oneself from decision-making when two competing organisations are involved.

143 Etzkowitz and Leydesdorff (n 31).

144 Following the rule: 'you need to invest money to generate knowledge; you need to invest knowledge to generate money'.

only be a response to lowering public R&D spending or a public image requirement[145] which obliges a university to enter into allegiances. Another concern is related to the commercialisation of new breakthrough technologies at the very beginning financed with public money but at the very end exploited mainly with and by private industry. The university governance problem arises, as concentration on exploitable short-term research erodes the knowledge base formation for future discoveries, and moreover challenges the existing status-quo.

Universities need to leave their ivory towers and involve themselves in economic activity but also in society through participative science, allowing for more interactive roles and transformative learning on both sides.

In advanced innovation ecosystems, universities are also supposed to carry out their important roles as enablers, catalysts for network formation, and even leaders of regional economic, institutional and social development, as well as regional innovation systems.[146]

There are also academia tasks that are in many cases forgotten but which stem from their very origin. These are 'the promotion of the general powers of the mind so as to produce not mere specialists but rather cultivated men and women, as well as "the search for truth", and the transmission of a common culture and common standards of citizenship'.[147] Therefore, in contemporary education, STEM fields (Science, Technology, Engineering, Mathematics) are overshadowing social sciences, not to mention Art (and Design), although some include this in the primary equation (STEAM).[148] Jerome Bruner goes further in defining the primary role of education as 'preparing students for the unforeseeable future'. In this sense, the generic abilities to learn, collaborate and create are becoming key, especially as the costs of learning these traits at later stages are much higher in comparison to accessing knowledge.[149]

During periods of more radical change, other academia commitments need to be considered, such as 'the role in the building of new

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145 Lowe (n 30).

146 Louise Kempton and others, 'Universities and Smart Specialisation' (European Commission, Joint Research Centre, SC Policy Brief Series 2013) <http://s3platform.jrc.ec.europa.eu/documents/20182/115084/JRC85508_Universities_and_S3.pdf/23a84c8b-233f-4cee-aae9-c89914f23e9c> accessed 24 September 2018; Renata Kubus, 'Política Regional de I+D+i En La Unión Europea' (XV Congreso Internacional de Contaduría, Administración e Informática - Universidad Nacional Autónoma de México, 2005).

147 Committee appointed by the Prime Minister under the Chairmanship of Lord Robbins, 'The Robbins Report' (1963) <http://www.educationengland.org.uk/documents/robbins/robbins1963.html> accessed 20 September 2018.

148 Stem to Steam <http://stemtosteam.org> accessed 20 September 2018.

149 Mulgan (n 28).

institutions of civil society, in encouraging and facilitating new cultural values, and in training and socialising members of new social elites',[150] ie a society transformation role.

The role of the government is not only relevant in overcoming market failure and providing roles for socio-economic circumstances through monetary policy, tax policy, standards, procurement, economic regulation, healthcare and education policy, market access, and so on.[151] It is essential in vitalising and financing basic research[152] and incubation, as well as providing venture capital for very new ideas and technologies.

The current state administration and validation role in regulating market operatives is being disrupted by blockchains,[153] allowing for distributed control through confirmation among users supported by a network. They are already used for the food banks of the United Nations, environmental protection and voting systems.[154] Related to this tendency, digital/crypto currencies are also emerging, replacing central banks and clearing houses and other intermediaries in some parts of the monetary system, apart from being a speculative bubble.[155]

The government opens itself to society and introduces forms of participative democracy in 'wicked' problem assessment. Democratic governance, especially in the context of the knowledge society, where the (over)application of scientific rationality in public policymaking, with the increasingly important role of professional expertise, is considered by many to be a critical issue of our times. Fischer stated that 'the division between those with and without expert knowledge will be one of the basic sources of social and political conflict in the new century'.[156] Technocratic ways of thought and action are prone to increase apathy towards political institutions in the attitudes and behaviour of citizens. The social and technical complexity of modern societies is easily turned into the main excuse to deny citizens a place and voice at the decision-making table, while it appears that citizen participation, understood as delib-

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[150] John Brennan, Roger King and Yann Lebeau [2004] 'The Role of Universities in the Transformation of Societies: An International Research Project' (Centre for Higher Education Research and Information/Association of Commonwealth Universities, UK).

[151] Egils Milbergs, 'Measuring Innovation for National Prosperity: Innovation Framework Report' (National Innovation Initiative, IBM Corporation 2004); Peterson (n 110).

[152] Peterson (n 110).

[153] Blockchain <https://www.blockchain.com> accessed 20 September 2018.

[154] Ágora <https://www.agorarsc.org/el-criptoismo-la-proxima-revolucion-economica/> accessed 20 September 2018.

[155] Douglas Rushkoff, *Throwing Rocks at the Google Bus. How Growth Became the Enemy of Prosperity.* (Profile 2016).

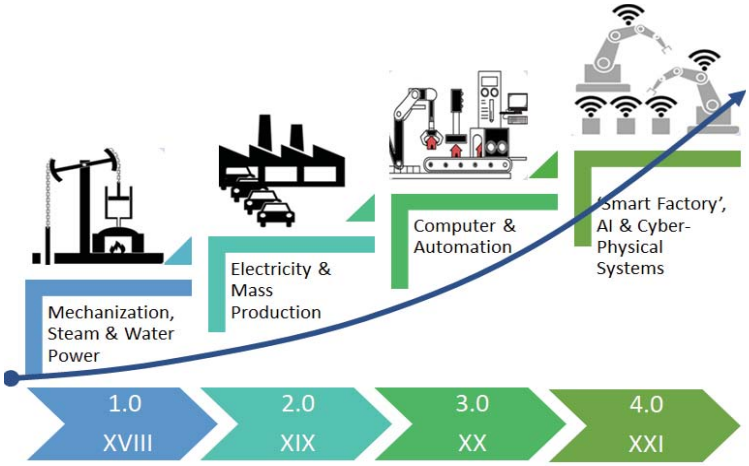
[156] Frank Fischer, *Citizens, Experts, and the Environment: The Politics of Local Knowledge* (Duke University Press 2000) x.

eration on the issues affecting their own lives, not only gives meaning to democracy and legitimises policy development and implementation, but also 'plays an important educational and psychological role in the social development of the individual citizen'.[157]

The raw material of democracy is individual creativity and collective imagination. At a time of immense atomisation, there is a need to shift the culture of society[158] back and towards its basic ideals, and cultural institutions in particular must lead the way.[159]

Currently the concept of Industry 4.0[160] is being set out. Due to 3D printing, nanotechnology (sensors), digitisation, and the 'internet of things', all production processes are becoming more flexible, less resource consuming, and in many cases can lead to the replacement of products by services.

Figure 9: Industry 4.0.



Source: own diagram; various sources.

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157 Fischer (n 156) x.

158 Jordi-Jesús Muñoz, 'Intercultural Europe: Cultural Diversity in the EU and the Debate on a Common European Cultural Identity' (2017) 30 Papeles de Europa 149.

159 Deborah Cullinan, 'Why Cultural Institutions Must Lead the Way' Stanford Social Innovation Review [2017] <https://ssir.org/articles/entry/civic_engagement_why_cultural_institutions_must_lead_the_way> accessed 20 September 2018.

160 The term of Industry 4.0 has its origins in the 2010 Hannover Trade Fair, developed by the German National Academy for Science and Engineering - Acatech. Federal Ministry of Education and Research <https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html> accessed 20 September 2018; Platform Industrie 4.0 <https://www.plattform-i40.de/I40/Navigation/DE/Industrie40/WasIndustrie40/was-ist-industrie-40.html> accessed 20 September 2018.

The role of industry is important in education in advanced innovation ecosystems, especially in applied and translational research. Afterwards, it is important not only in the role of internal implicit innovation[161] but also incubation, firm formation and related activities, as well as in providing venture capital. The overwhelming requirements of strict industry costs and therefore price control need to be carefully reconsidered, as there is a risk of their externalisation to society, when workers with short-term contracts and low income necessarily require support from public funds, if not to survive while working, then afterwards for retirement and health and welfare issues in general.[162] Industry can also promote development in the marginalised parts of society, providing for more inclusiveness and treating beneficiaries as clients and a part not only of the problem but also the solution.

Business assuring profits is not sufficient in the complex hyperconnected world of today. Industry requires society to be customers that can afford its products but also to be educated, motivated, ethical employees and reliable, efficient suppliers. This means that 'businesses benefit from social stability and broad prosperity'.[163]

More and more companies and entrepreneurs are trying to apply open innovation strategies, and in this way increasingly perform as 'hubs for an ecosystem of suppliers, customers, infrastructure and sources of knowledge'.[164] 'Business models are striving to link and leverage these external innovation assets to create new possibilities for optimizing the value of the whole and also the power of collaborative advantage'.[165]

The thoughtful, considerate, ambitious and farseeing attitude of business and industry (as far as societal norms and values are concerned) is also focused on counteracting the negative effects of the acceleration of economic processes due to globalisation (free trade, increased foreign investment and the movement of capital), and finds its expression in forms of corporate social responsibility (CSR) and civic involvement.[166]

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161 Pedro Canovas Tamayo, 'Innovación Tecnológica y Crecimiento En La Unión Europea' (2014) 20 Revista Universitaria Europea 137.

162 Jordi Merino Noé, 'La Mediación de Los Regímenes de Bienestar Sobre Las Condiciones de Trabajo, Empleo y Salud En La Población Asalariada Europea' (2018) 30 Papeles de Europa 125 <https://revistas.ucm.es/index.php/PADE/article/view/58671/52859> accessed 25 September 2018.

163 D'Andrea Tyson (n 46).

164 Milbergs (n 9) 2.

165 Milbergs (n 9) 2.

166 Goren Noren, 'The Role of Business in Society' [2004] Svenskt Naringsliv 1 <http://www.svensktnaringsliv.se/migration_catalog/the-role-of-business-in-society_532870.html/BINARY/The role of business in society> accessed 20 September 2018.

The civic involvement of industry is connected with being a good 'corporate citizen', implying a cultivation of respectful relations with various stakeholders. Corporate social responsibility is often described as a 'voluntary responsibility that transcends the demands of national legislation and encompasses human rights and environmental and social issues'.[167] CSR, even if trying to take root in sustainable development, is a narrower concept than civic involvement.

As the ecosystem evolves in the digital world era (3D printing but also, for instance, energy production),[168] the role of prosumers (producers and consumers at the same time) is becoming more prominent in original industrial settings but also through deliberative practices that allow thorough participation in the activities of government and academia.

Thus, society is taking an active role in the advanced innovation ecosystem. The society mindset is a characteristic affecting innovation. It includes 'youth interest in science, cultural factors, and science literacy, entrepreneurial attitudes and openness to collaboration'.[169] On the other hand, interest in art can also be used as a predictor for innovation and entrepreneurship at the personal level.[170]

It is indeed possible to propel the evolution of the society mindset and innovate new forums, eg participatory inquiry, which can positively side-step what could become an impasse between citizens and experts. However, they need to be organised, facilitated and nurtured further. Not being a magic cure for all social and economic problems, participatory inquiry holds out 'the possibility of bringing forth new knowledge and ideas capable of creating and legitimating new interests, reshaping the understanding of existing interests, and, in the process, influencing the political pathways along which power and interests travel'.[171]

A real cause of concern is that innovation tends to exacerbate existing imbalances, displacement and substitution, and favours a few selected actors. To counter this tendency, smart regional specialisation has emerged to engage local actors due to their proximity. In addition, a separate domain of geography of innovation deals with spatial allocation:

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167 Noren (n 166) 3.

168 Kirsi Kotilainen and others, 'Prosumer Centric Digital Energy Ecosystem Framework' in *Proceedings of the 8th International Conference on Management of Digital EcoSystems - MEDES* (2016) 47 <http://dl.acm.org/citation.cfm?doid=3012071.3012080> accessed 20 September 2018.

169 Milbergs (n 9) 11.

170 Laura Niemi, 'The Arts & Economic Vitality. Relationships between the Arts, Entrepreneurship & Innovation in the Workplace' (working paper 2012) <https://www.arts.gov/sites/default/files/Research-Art-Works-BostonCollege.pdf> accessed 26 September 2018.

171 Fischer (n 156) xii.

> Challenging the methodological emphasis of scientific experts on 'generalizable, technically rational knowledge', postpositivist theory underscores the importance of bringing in the local contextual knowledge with sociocultural orientation of the ordinary citizen.[172]

Participatory inquiry has the potential to provide new, local knowledge that is not within the reach of more abstract empirical methods. It is especially crucial for new knowledge related to environmental issues and impacts, where there is a high level of wickedness and scientific uncertainty, and it is society that is becoming the real laboratory for acquiring the knowledge of the consequences of its implementation, eg in the case of nuclear power stations, where little was known about the consequences of the moral hazards until the occurrence of events with 'almost completely safe' installations or products that proved not to be so.[173]

A more discursive, participatory mode of policy expertise is required with a new understanding of the expert as a 'specialized citizen'[174] as opposed to the current increasingly technocratic, elitist policymaking processes. From this perspective, it can also be understood as a role exchange, with scientists taking on the role of facilitators and citizens, in some sense, taking on the role of scientists.

Explicitly developing Carayannis and Campbell, the social dimension and further democracy are crucial because the institutional configuration and arrangements of industry, academia and government should 'serve society, and the society should serve the people and individuals as humans (and not the other way around)',[175] always bearing in mind the (natural) environment.

The environment stands here for the physical (natural) localisation of innovation ecosystems. Building on Soddy:

> *The problems standing in the way of well-being and prosperity are an unsound, never challenged modern monetary system and a lack of consideration and understanding of the physical reality underlying economics. What in modern school passes for economics is really the study of debt or chrematistics. Chrematistics, as the study of wants and demands and of how they exchange for one another, is more plainly termed commerce.*[176]

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[172] Fischer (n 156) xii.

[173] As in the case of Chernobyl or the Fukushima Daichi nuclear disaster.

[174] Fischer (n 156) xiii.

[175] Carayannis and Campbell, 'Developed Democracies versus Emerging Autocracies: Arts, Democracy, and Innovation in Quadruple Helix Innovation Systems' (n 37) 2.

[176] Frederick Soddy, *Wealth, Virtual Wealth and Debt. The Solution of the Economic Paradox* (2nd edn, Britons Publishing Company 1933) 78.

For innovation, a region or localisation (especially megalopolises), as spaces for knowledge, consensus and thus innovation itself,[177] are key notions. 'Critical mass' is in this sense a concentration of research resources on a particular topic from which technological ideas can be generated. It is especially relevant when different actors become implicated and cover gaps, many times resulting in the creation of a hybrid organisation focused on innovation and regional development.

This also responds to the changing approach to the economy which Boulding[178] called the transition from the open 'cowboy economy' to the closed 'spaceman economy'. The illimitable plains ready for discovery and exploitation are replaced with the Earth becoming a 'single spaceship[179] without unlimited reservoirs of anything, either for extraction or for pollution'.[180] As with the cyclical ecological system, so with the circular economy. The circular economy concept was first introduced formally by Pearce and Turner in 1989.[181] The difference between the two types of economic approach is seen in the attitude towards throughput, consumption and production. In the open cowboy economy, throughput is the measure of success of the economy, with Gross National Product (GNP) being a rough measure of it. Following Boulding, 'the essential measure of the success of the [closed spaceman] economy is not production and consumption at all, but the nature, extent, quality, and complexity of the total capital stock, including in this system the state of the human bodies and minds'.[182] Thus, the aim of a closed spaceman economy is stock maintenance with a lessened throughput thanks to technology. The welfare of the human and natural environment needs to be considered in any case, whether it be in terms of stock or flow variables. From a cognitive history perspective, this would be a change from the cultural metaphor of the 'conquest of nature' to the 'web of life'.[183]

The introduction of the social dimension into the circular economy framework is ongoing.[184] Social innovation and collaboration economy based companies are especially important in this sense. Furthermore,

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177 Etzkowitz (n 3).

178 Boulding (n 7).

179 A term also used and popularised by Buckminster Fuller.

180 Boulding (n 7) 6.

181 David W Pearce and R Kerry Turner, *Economics of Natural Resources and the Environment* (Johns Hopkins University Press 1990) 73.

182 Boulding (n 7) 7.

183 Lent (n 13).

184 Allan Murray, Keith Skene and Kathryn Haynes, 'The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context' (2017) 140 Journal of Business Ethics 369.

they can be seen as the proof-of-concept laboratories for public policy, activating change-makers at the community level.

There are also modern forms of management of organisations, schools or local communities called sociocracy[185] that can be traced back to August Comte, and seen by him as 'the social order of the future'. Sociocracy supposes management in circles, where everybody's opinion should be considered and consent is required. Its appeal is in uncovering the potential of collective intelligence. Dragon Dreaming[186] is another innovative management methodology that bears in mind sustainability in all dimensions.

The joint framework also allows for a new approach to sustainability governance known as Transition Management,[187] leading to policy recommendations that can be discerned in the process.

7 Conclusions

The conceptual framework developed in this study is aimed at providing a more comprehensive and dynamic perspective of innovation ecosystems, showing the actors and processes of innovation origination and disruption to it. It aims to complement already existing research on the subject.

It is to be used as a tool for assessing the maturity of the innovation ecosystem. The research at the European Union level can be applied to the EU in general and also individual countries, studying all the actors/ innovation helix strands involved and their stage of innovative capacity development. The static conditions of three helixes: government, academia and industry have already been quite well studied, for instance in the European Innovation Scoreboard.[188]

In particular, dynamic conditions are seen as the main input of this study, and the kinds of interrelations between different helixes would be

[185] Sociocracy 3.0 <http://sociocracy30.org> accessed 21 September 2018.

[186] Dragon dreaming <http://www.dragondreaming.org> accessed 21 September 2018.

[187] Derk Loorbach, 'Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework' (2010) 23 Governance 161 <http://doi.wiley.com/10.1111/j.1468-0491.2009.01471.x> accessed 5 October 2017; B Elzen, *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy* (Edward Elgar Publishing 2004); Umberto Pisano, 'Transition Management as a Governance Tool for Sustainable Development' (European Sustainable Development Network Case Study No 17, 2014) 11; Felix Rauschmayer, Tom Bauler and Niko Schäpke, 'Towards a Governance of Sustainability Transitions: Giving Place to Individuals' (UFZ Discussion Papers 17, Helmholtz Centre for Environmental Research (UFZ), Division of Social Sciences (ÖKUS) 2013) 97.

[188] European Commission (n 33).

a good indicator, especially tri- or multilateral agreements,[189] as well as the circular approach or participative democracy and scientific involvement and developments.

From the process perspective, innovation (entrepreneurship) incubation seems to play an especially vital role. Thus, actor implication assessments are envisaged. Intermediary organisations in the European Union, such as science parks, incubators and venture capital, as well as different forms of innovation hubs or labs have been revised. Social innovation initiatives, such as the collaborative, sharing economy[190] are also spreading. It will be interesting to study them, including in some cases as proof of concept (or sandboxes) for further public policy innovations.

The final part of innovation process development (institutionalisation or landscape level spreading) is, however, also an interesting way to assess the innovation propensity of a country or the European Union. The involvement of the arts and society at this stage is crucial.

It is important to add that there are also additional elements not directly related to innovation but which influence their rate and direction,[191] such as general economic environment conditions, especially global ones.

Three different kinds of relations are distinguished in innovation ecosystems. These are intra-relations inside each vertex, defined by the capacity to perform their roles; vertical and more complex horizontal interrelations among different vertices: university, industry, society and their (natural and local) environment; and extra-relations between the innovation ecosystem and its external environment, understood as collaboration with the ecosystems of other countries/regions.[192] In particular, the possibility of fruitful collaboration with another innovation ecosystem depends completely on its development and advancement level. At some very basic stages, it can lead to dependency on foreign technology and brain drain.[193] This also holds true for innovative companies' reallocation to more advanced innovation ecosystem environments where

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189 Bilateral agreements have also been quite well studied, for instance María Bujidos-Casado, Julio Navío-Marco and Beatriz Rodrigo Moya, 'Análisis de La Innovación En Colaboración de La Empresa Europea Con La Universidad: Evolución 2008-2014' [2017] Revista Universitaria Europea 23.

190 Pablo Rodrigo Torralba and Sara González Fernández, 'Economía Colaborativa: Una Nueva Actividad Económica Para Un Nuevo Sistema' [2018] Revista Universitaria Europea 23.

191 Milbergs (n 9).

192 Sábato and Botana (n 34).

193 Sábato and Botana (n 34).

they have their needs better attended to through the denser and better articulated interconnection of the system.

This innovation ecosystem framework can also be assessed for innovation sector development, such as the nanotechnology sector. It can give another framework use perspective, allowing the stage of innovation development and actors' preparation for a specific sector to be assessed.

The indicator choices are based on their appropriateness for the framework and also their availability. The density of the innovation ecosystem is considered as being basic to their advancement. However, a more networked system does not necessarily mean a more intelligent one. 'Collective intelligence can be light, emergent and serendipitous, but more often it needs to be consciously orchestrated, supported by specialist institutions and helped by common standards'.[194] In the process, we can connect the technology with the power of human intelligence. For this purpose, we need to carefully revise the learning loops, especially their more evolved levels.

The participative process to assess the proposed framework can hopefully be carried out, establishing the procedure and ways to include it in the findings of innovation ecosystems studies.

As expressed by Fischer, the importance of academia and knowledge is 'lodged less in the central position of the expert in the decision-making structures than in the impact of expert discourses on the way we understand and organize the world'.[195]

[194] Mulgan (n 28).

[195] Fischer (n 156) 2-3.