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Views & Comments

A Research and Innovation Policy for Sustainable S&T: A Comment on the Essay "Exploring the Logic and Landscape of the Knowledge System"

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1. Introduction

In recent years, the need to face major global challenges has made it necessary to review strategies that address multifaceted contexts. Economic, societal, environmental, and technological dimensions all act together as major drivers for change, and science and technology (S&T) programs aimed at research and development (R&D)-performing communities constitute an important asset in generating emerging and breakthrough solutions in the international transition toward the knowledge economy.

Not long ago, I read a scientific paper published in a scientific journal [1] that proposed an interesting logic as a way of approaching a cultural transformation of S&T; the paper suggested a rethinking of the current system from the demand-driven perspective based on "unresolved problems" that is central to the knowledge economy. I was attracted by this paper, since even though the rate of global publication of scientific papers is impressive, essays on cultural transformation in S&T are rarely published in scientific journals. Many interesting papers on the knowledge economy appear in socioeconomic journals, however, thus generating a communication gap between scientific and socioeconomic cultural domains. For this reason, when viewed in this light, the paper I read was rather unique; it provides a forward-looking and high-level message that deserves attention from policy-makers and scholars in research and innovation (R&I) activities.

In his paper, titled "Exploring the logic and landscape of the knowledge system: Multilevel structures, each multiscaled with complexity at the mesoscale," Professor Jinghai Li foresees a cultural transformation, and elaborates a novel multilevel approach to develop a new knowledge context that describes relationships to meet R&I purposes. This system-oriented approach can drive decision-makers forward to create a deep change in scientific and technological knowledge generation, production, and delivery at all levels.

This cultural aim is the immediate merit of Li's work. Coming from a solid background in process engineering, Li dares to develop an ambitious proposal for a collective and system-thinking effort. He frames core elements of huge transformative processes at the macro level that will help to shape the knowledge system of the next decades.

2. Summary of the structure of Li's paper

(1) **Breaking habitual thinking patterns**. Here, the paper starts with a report on major questions facing contemporary science, such as the current debates on science reductionism and holistic perspectives. An examination of major results that have been achieved through science reveals the essential role played by S&T in world-changing breakthroughs. The paper suggests establishing novel correlations among S&T disciplines and identifying pathways toward a new layout of the S&T system; it also describes possible actions to drive forward a new paradigm for a global shift.

(2) **The contemporary knowledge system**. Next, the paper describes the current state of the knowledge system and introduces "mesoscale complexity" as a locus for emerging research on advanced solutions. The author explains the multilevel, multiscale attributes and mesoscale complexity of a proposed model for integrating S&T knowledge into a single landscape. Nevertheless, the meanings of these terms—multilevel, multiscale, and mesoscale—deserve to be addressed according to the state of art in the literature to facilitate communication exchange.

(3) **Closing gaps in the existing knowledge system**. The paper then focuses on the existence of gaps in the knowledge system and on the key role of a unified mathematical framework in modeling systems for multi-objective problems. A situation involving mesoscale problems—the energy-minimization multiscale (EMMS) model—is reported, along with a suggestion to review competition and dominant mechanisms in order to introduce a transdisciplinary approach. According to Li, doing so may lead to a different S&T landscape, with associated risks. In line with this perspective, the mesoscience program launched by the National Natural Science Foundation of China (NSFC) is reported as a novel approach in the design of energy-related research programs.

(4) **The formation of a new scientific paradigm**. Here, the paper provides guidance on transitioning into the change, and highlights the role of information and communications technology (ICT) as a major enabler. Li points out that current research methods are dominated by analysis, deduction, and determinism for numerical and graphical simulations, and that deep changes in research methods to exploit new measurements and experimental techniques will lead to breakthrough results. High resolution in

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time and space is required for future scientific research and for related methods and dynamic, nonlinear, non-equilibrium, and system theories.

(5) **Conclusions**. Finally, Li remarks on the need for a new way of thinking about the S&T landscape, and for a paradigm shift that redefines space and establishes sustainable transdisciplinary research activities for science and innovation.

With his article, Professor Li's intent was to open up a reflection: first, on the need to design a pathway for a sustainable future for S&T; and second, on the need to share with other S&T systems this conceptual approach to a new paradigm for scientific research. Professor Li addresses the need for a paradigm change in order to explore "focal yet unresolved problems" that are common to many S&T systems around the world. Responding to as yet unresolved problems will require multi-dimensional relations that cross the existing knowledge-production system, followed by a linking of science to technological development in order to create innovations for economic growth and environmental, cultural, and lifestyle benefits.

Each component in Li's proposal is logically framed within a conceptual model (Fig. 2 of Ref. [1]). In principle, this model promotes the goal of enabling dynamic interactions and the growth of new relationships among scientists, experts in various fields, research groups, and research-performing institutions with related communities of researchers. Section 3.5 of Li's work describes the common attribute of the four categories of science in order to generalize the complexity that is needed to respond to unresolved focal problems.

This conceptual model (Fig. 2 of Ref. [1]) holds the capability to evolve into a so-called "reference model," as it is used to support and drive forward the transformation of real settings and actors. Its use in this way may enable a static view of the knowledge system to become a useful tool for devising a broad, cross-thematic, and forward-looking perspective of emerging sciences. Using the conceptual model as a reference model will change it from a visionary logic of an ideal knowledge system into real, vital, and forward-looking S&T progress [2].

The energy needed to generate the missing linkages and pathways, however, requires a mixture of top-down and bottom-up strategies for a collective sharing of basic principles, of the expected benefits and adaptation needs, and of regimes to include, accompany, and valorize existing efforts and to create novel hubs for new knowledge.

Li poses relevant questions regarding the "contemporary knowledge system" and the need to pay attention to the complexity that characterizes knowledge gaps in contemporary sciences, bridging scientific as well as social disciplines regarding families, cities, and territories. Existing common challenges and problems require a great deal of effort and combined approaches in order to develop theories, principles, methods, and tools required to achieve radical innovations in S&T. The new paradigm of scientific research suggested in Li's work outlines the life-cycles of S&T activities (Fig. 4 of Ref. [1]). The description shows the actual growth of interdependencies among scientific processes for studying physical and societal worlds. The world complexity requires high value observation with related empowered data-driven and virtual representations.

In this way, Li describes three approaches for developing transdisciplinary in research activities (Fig. 5 of Ref. [1]). These three approaches can become key factors in a "driving model" to provide a guidance to mobilize interested S&T groups and other actors in exploring cross-cutting principles, in attaining high-level transformative outcomes and in building a wide-scale participation.

To promote the paradigm shift suggested in his article, Li urges readers to consider the relevance of "big data, science clouds, and open data." Future-oriented data strategy is a key driver in changing research methods and it will generate impacts on learning and sharing processes in science and society.

3. Possible turning points of the paper

3.1. De-siloing

Breaking down habitual thinking implies a change of research mindset; such a change would enable a paradigm shift to allow us to face the world's complexity. Li's article addresses some specific S&T situations. For example, addressing the mesoscience in an institutional program can be important in clustering S&T domains with related research groups. The intrinsic value of desiloing is to accelerate the study of mesoscale problems and promote transdisciplinary and interdisciplinary approaches. However, conceptual representations and high-level models must be discussed further in order to share high-value relationships with existing S&T communities in related as well as diversified contexts. On their own, conceptual models may be weakly or wrongly perceived by the S&T community, as researchers are deeply committed to their activities and are fully engaged in the daily running of research activities in labs and projects. On the other hand, policy-makers, citizens, and industries may be attracted by efficiency gains and motivated to support efforts toward high-level S&T goals. The call for wider scientific engagement requires to foresee the coming transformation and to identify a governance to rule the entire S&T process in a defined time-horizon. To this end, a policy for S&T programs for sustainable growth could engage major stakeholders. This policy supported by a sense-making process can enable to envisage potential leveraging success and competiveness while contributing to the development of an integrated view, durable in terms of both time and total quality.

3.2. Collaboration, cooperation, coopetition, and competition

S&T development requires group competence and skills at many levels. This point is examined in the paragraph in Li's work that discusses the "formation of a new scientific research paradigm," and that describes the need for specific teams, interdisciplinary divisions, transdisciplinary centers, and common platforms. However, in order for this organizational approach to respond to S&T demand, it must also consider new relationships, schemes, and agreements for purpose-oriented, agile, efficient, trustable teamwork. Collaboration schemes must be built and developed around S&T purposes and ruled by research institutions in order to enhance and ensure S&T excellence. To bridge and add high value to diverse perspectives, different policy choices for teamwork schemes are available; these can be implemented in order to foster high-added-value relationships. Collaborations are the primary arenas to leverage waves of S&T knowledge in order to integrate research activities and enable—through multiple and different types of agreements—interfaces between members of the international community.

Cooperation represents a specific form in order for partnerships to be established; this can be a generic frame for developing specific research initiatives and enabling the mobility of competences.

An alliance is a form of cooperation that aims to create a synergy among hybrid parties that are interested in the subject and that expect potential mutual benefits. In this context, an alliance is also a form of organization that requires specific actors with R&I instruments in order to enable multiple stakeholders to sign agreements to address high-level objectives of common interest.

The evolution and consolidation of relationships, represented already today by labs, projects, and flagships, in the near future will reveal a highly dynamic context managed through a variety

of legal instruments, currently part of advanced science management at global level.

In this evolving context early phase of knowledge development, researchers should be motivated to develop a "pre-competitive spirit," which is then followed by a "coopetition approach" as a prerequisite for enhancing talents and the societal value of science. Regarding coopetition, the principle of "compromise through competition" is very relevant, as pointed out by Professor Batterham [3] in his response to Li. Batterham strongly highlights "compromise through competition" as a general principle for advancing progress; it is of the utmost importance not only in science but also in the transformation process of the industrial economy. The role and success of platforms—not only online, but also in physical contexts—have demonstrated how important it is to create loci with events (such as summits) where direct experiences can be exchanged and individual competition can be driven forward through collective participation in any transformation process within the proposed model.

In the forthcoming period, new behaviors and team-building strategies will be key factors in developing an R&I community. In the European Union (EU), the European Multiannual Framework Program (MFP) represents a valuable experience of multinational collaboration for research, technological development, and innovation. Through expert evaluation and assessment, this EU program for R&I strongly contributes to knowledge and innovation developments in real settings by facilitating "collaboration partnerships with related joint initiatives crossing countries" in order to enable research excellence and pre-competitive projects.

3.3. Resilience, group interdependency, and territory

Professor Li remarks on the value of envisaging proactive behavior and promoting early understanding of the ongoing transformation of S&T. Doing so may help S&T communities, policy-makers, and other actors to analyze solutions supported by a dedicate forward-looking rolling program. As discussed above, Li's conceptual model can become a reference model for specific consultations and can be used to create momentum to promote the need to approach this new landscape of achieving S&T effectiveness coupled with efficiency gains.

Resilience helps to improve mutual connectivity between resources and distant cultural approaches; it also helps to enable the design of S&T programs and actions at the macro level along with operational levels for S&T research and for policy investments in the sustainability of science.

In this evolving landscape, it is important to consider the actors and recipients of the solutions: the cities, territories, and societies, with all their differences. In such a complex environment and with such a high degree of economic interdependency—which has also been addressed for the Eurozone political economy—a variety of solutions can be tailored, involving actors at multiple levels (i.e., supranational, national, regional, and sectoral), to meet expectations. Therefore, sound reflections are on the political floor and can guide forward S&T role and activities to achieve breakthrough solutions in multiple areas.

Li emphasizes that in order to transform the present layout of the S&T system, it is important to move into a new logic that looks for excellence in interdisciplinary research; this requires educational systems to play a role in engineering the cultural development of young generations while considering the value of cultural roots [4].

4. Concluding remarks

The paper of Professor Li foresees a cultural transformation, based on a novel multilevel approach and built on relationships to meet R&I purposes in the next decades. Therefore, Li's paper presents an integrated forward-looking vision of new sciences as well as the need of S&T development with the aim to face current changes induced by breakthroughs in research methods, theories, technologies, and impacts on society as a whole.

This commentary highlights some turning points of S&T collaboration and cooperation considering multiple actors at multiple levels (supranational, national, regional, and sectoral).

I had the chance to contribute to a similar transformative effort in 2005 within a huge European initiative during the initial phase of globalization. In order to accelerate a transformation process, to have a model is an advantage and merits the commitment of interested actors and systemic confrontation with policy-makers for developing the right operational conditions. Forward-looking activities can have part in this, to provide a sense-making approach and allow people, cities, and territories to be aware of the need of a transformative process. Participants have to develop capabilities in response as well as new competences. Regarding the development of an S&T policy, in the EU, every seven years the EU Framework Program is built on a strategic design-thinking approach for R&I with extended consultations; it represents a strategic enabler for S&T cooperation. This EU program renovates the way research activities and funding allocation are assigned through competitive calls to excellent R&I partnership from member states. This supranational policy implies different levels of agreements based on multilevel schemes and instruments that form the European cooperation context built on trust and reliability among different types of partners and member states.

It is my belief that the paper by Professor Li can guide our common thinking forward and open up new pathways for understanding global sustainable S&T and for absorbing, filtering, and assessing societal concerns as part of high-level scientific knowledge development. The model proposed by Li provides common principles to consider in S&T to respond to grand challenges with advanced high-level research solutions.

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