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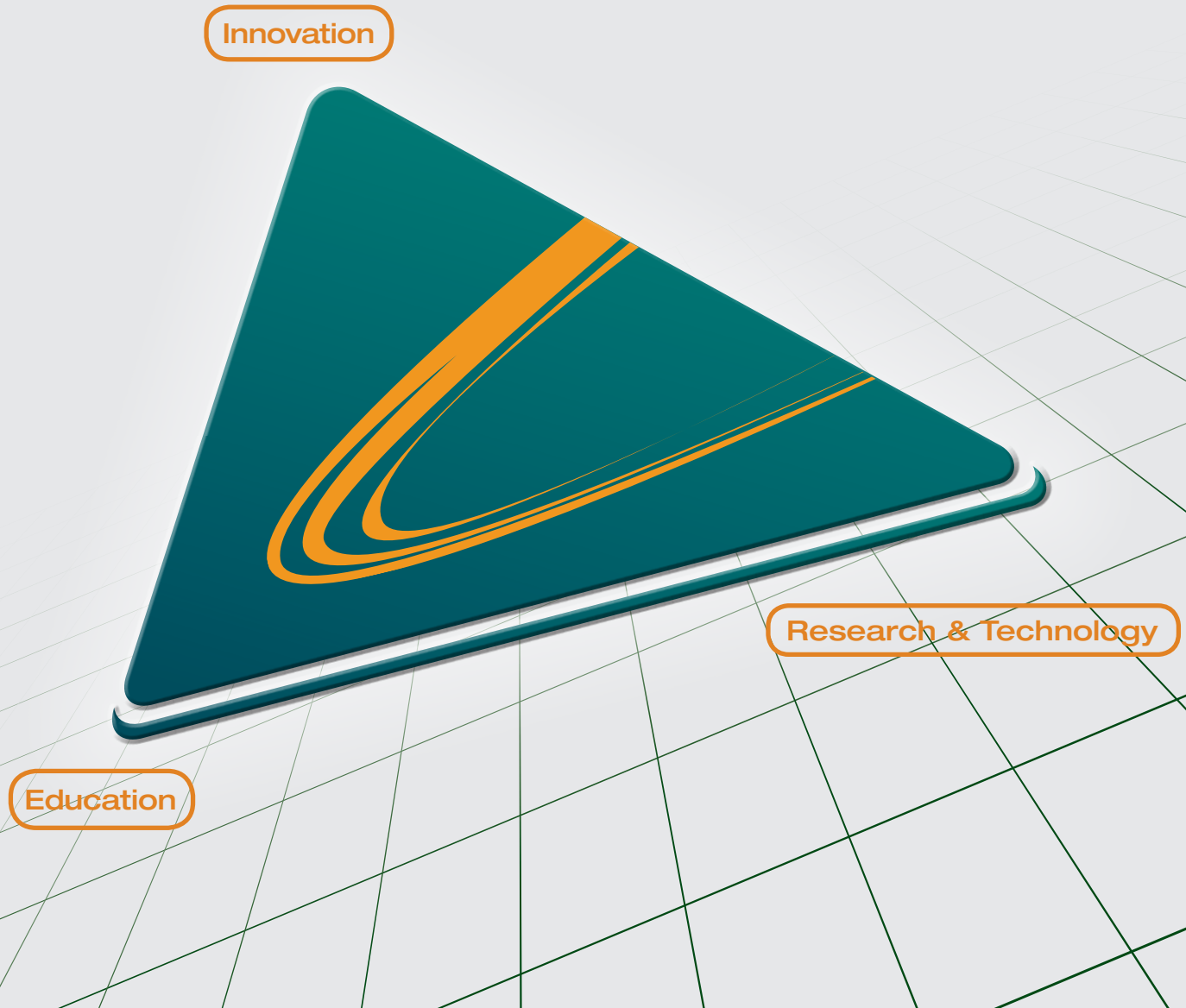
OECD HIGH LEVEL EVENT ON THE KNOWLEDGE TRIANGLE:

Enhancing the Contributions of Higher Education and Research Institutions to Innovation

Paris, 15-16 September 2016

Policy paper by keynote speaker H.E. Manuel Heitor
Minister of Science, Technology and Higher Education, Portugal



OECD High-Level Event on the Knowledge Triangle:
Enhancing the Contributions of Higher Education and Research Institutions to Innovation

Paris, 15-16 September 2016

Open the box in times of uncertainty:
Fostering networks of opportunity through collaborative laboratories and learning landscapes, together with global research networks

A Policy Paper

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Summary

This policy paper attempts to enlighten new insights in science, technology and innovation policy for OECD countries under a context of increasing uncertainty. The analysis calls for the need to strengthen the investment in research and education through the advanced qualification and employment of **skilled human resources**, emphasizing the role of **"learning by research",** together with adequate **institutional, spatial** and **international** *relational frameworks*, under three main lines of action and scope:

- Institutional: The increasingly relevant role of **"learning by research"** and the increasing interaction of research and higher education institutions with **intermediaries**, requires opening-up science and innovation policies to multiple public and private agents in the form of ***collaborative laboratories***, regarding risk-sharing partnerships among government, industry and academia. They should be oriented towards ***experiential learning*** activities and **skilled employment** and considering a wide diversity of research activities, including "frontier and discovery research", the translation and diffusion of related knowledge (i.e., "translational research") and "professional practice based research" oriented towards the advancement of professional activities;
- Spatial/local: Paradoxically, place matters more than ever and this calls for policy actions oriented towards the spatial dimension of knowledge and in a way to guarantee strengthening "**knowledge-based urbanism**". We refer to turn the built environment associated to higher education and scientific campuses into ***learning landscapes*** to foster the way higher education and research institutions promote the territory at large. They should nurture and strengthen their relation with society and the economy through forms of **collaborative learning spaces** stimulating knowledge and innovation. This suggests the importance to rethink not only the social matrix of learning spaces – the modes of teaching and learning - but also the physical settings that support co-creation activities in continuous interaction with key stakeholders.
- International: **global research and innovation networks** towards socio-economic resilience also play an increasingly relevant role as a new paradigm of **structured international higher education relationships** is emerging as shaped by a new era of government and industry intervention in association with knowledge. They are driven by political and economic interests, but also by an increased perception of the growing perceived evidence of the potential benefits resulting from the economic appropriation of the results and methods of science by society.

In addition, it is argued that the OECD should help clarifying the role of private and public incentives to support R&D and innovation, namely in terms of fostering a non-hierarchical integration of formal policies and informal system linkages leading to knowledge-driven societies in times of increasing uncertainty. This requires the continuous adaptation of systems of competence building and innovation, among which promoting global research and innovation networks should be highlighted.

1. Introduction

Which challenges and opportunities for policy making in order to better integrating education, research and innovation activities of higher education institutions (HEIs) and public research institutions (PRIs) to foster greater synergies and impacts from public investments in education and research at the local and global levels?

This policy paper attempts to address this question and its basic premise is that the central locus of innovation has increasingly become distributed and increasingly dependent upon linkages between many different institutions and sources of knowledge. First, the increasingly transnational business, technology and science require evolving from *national* approaches to new collaborative policy frameworks. Among these, large international collaborative arrangements play an emerging role. Second, the science and technology performance sectors, namely government, industry and academia, remain key players, but the connectivity, links and associations with other institutional players and agencies is no less important. In particular, the increasingly relevant role played by intermediaries and new technology-based firms is identified, which are also becoming global. This requires opening-up science and innovation policies to multiple public and private agents and promoting global research networks towards socio-economic resilience.

At a time of increasing financial difficulties derived from public budget constraints[1], there is the expectation that the links between research activity and its application in society will be reflected in more direct and immediate financial flows. However, this perception is leading to an institutional convergence between what universities do (and are supposed to do) and what firms and other agents do.

In fact, more than a decade after Burton Clark launched the idea of "entrepreneurial universities"[2], there is still much to learn about their impact and analysis has clearly considered this convergence a potential threat to the institutional integrity of the university and the future of scientific research due to the commoditization of knowledge[3].

The issue is not to "save the university", but rather to understand who will play the fundamental and unique role that universities have played in the overall cumulative system of knowledge generation and diffusion. It is clear that elites in most OECD countries are not willing to allow this integrity to be jeopardized. By misunderstanding national policies towards university-based research, there is a grave danger that university policy worldwide will destroy these basic functions, which would be detrimental to the global production of knowledge, but would also certainly harm the development prospects of many OECD regions.

Overall, changing the 'one size fits all' patterns of teaching and learning, making students' work more socially responsive, by fostering reflexive practices and student-centered learning schemes, are the ultimate goals of many leading institutions, which should be better understood at an overall level. We need to allow students to determine their own learning paths and trajectories, particularly through education cycles, but also across institutions in different regions and countries.

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[1] Heitor, M. (2015). Science Policy for an increasingly diverging Europe. RT. Journal Of Research Policy And Evaluation, 3(1). doi:http://dx.doi.org/10.13130/2282-5398/4816

[2] B.R. Clark, (1998), "Creating the Entrepreneurial University. Organizational Pathways of Transformation." Oxford, Pergamon Press.

[3] R.R: Nelson (2004) "The market economy, and the scientific commons", *Research Policy* 33 (2004) 455-471.

The debate requires tertiary education institutions in general to better understand *how people learn*[4]. It is clear that learning systems vary considerably across the full spectrum of disciplines, with arts and medicine using competence-based and hands-on learning approaches and, probably, engineering and the basic and social sciences following a more intense academic drift, relying on deductive strategies, with principles first and applications later. The book by Tony Wagner[5] of Harvard, as well as that published by Douglas Thomas and John Seely Brown[6], represent insightful treatments about this theme.

Following the practices, skills, attitudes and values described above, education at all levels should take into account that learning a new practice requires moving through discovery, invention, and production not once, but many times, in different contexts and different combinations[7].

To achieve these objectives, we must learn from new research and, certainly, we also need to foster evidence-based project and experimental work, as well as to focus our attention on the transferable skills students should acquire. But we also need to reduce drop-out rates in tertiary education and to involve students in research activities from the early stages. In summary, we need to go beyond the conservative structure of tertiary education and gradually concentrate our efforts on measuring and taking stock of the diversity and evolution of specific student-centered parameters.

But, in addition to that argument, we argue for a deep discussion about the complexity of stakeholder engagement and the politics of trust building in science and technology.

This is because, beyond any single measure, one may argue that it is the public understanding of science and the related level up to which people trust in academic and scientific institutions that determines the success of the politics of science and innovation policies. It is under this context that the systematic development and promotion of activities to foster science awareness, science education and the role of science in the daily life of citizens has been implemented in many regions and countries with a high level of priority in the innovation policy agenda.

2. Research, education and socio-economic resilience

It is clear that *technoglobalism*[8] and the globalization of trade and supply chains led to the emergence of increasingly competitive global markets and to facilitated access to new suppliers, independently of their geographic location[9]. This has allowed countries and regions with strong technological and industrial bases to profit on the lowering of trade barriers to access new markets, while the majority of firms located in other regions remained confined to local markets.

In addition, the analysis of the overall trend on moving towards knowledge intensive services and its relation with job creation and economic growth requires some pragmatism. This is because, in parallel to *technoglobalism* came post-industrialism, promoting services

[4] National Research Council (2000), "How People Learn: Brain, Mind, Experience and School", J.D. Bransford, A.L. Brown and R.R. Cocking, Eds., Committee on Developments in the Science of learning, Commission on Behavioral and Social Sciences and Education, National Research Council, Washington, D.C.
[5] Wagner, T. (2012), "Creating Innovators: The Making of Young People Who Will Change the World", Scribner, New York.
[6] Thomas, D. and Brown, J.S. (2011), "A New Culture of Learning: Cultivating the Imagination for a world of constant change",
7 European Commission (2007). Science Education now: A renewed pedagogy for the future of Europe. Eds., Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., Hemmo, V.; Directorate-General for Research, Science, Economy and Society, EUR Report 22845, European Commission.
[8] Ostry, S. and Nelson, R. (1995), "Techno-nationalism and techno-globalism: conflict and cooperation", The Brookings Institution, Washington.
[9] Berger, S. (2005), "How we compete – what companies around the world are doing to make it in today´s global economy", Doubleday Press.

as the new developed countries' economic growth overtook manufacturing industries. Captivated by the prospects of accelerated and cost-effective economic growth, many countries, the United States included, started shifting their focus from manufacturing industries to knowledge-intensive services (Hepburn, 2011[10]; Ghani and Kharas, 2010[11]).

Following many OECD reports over the last decades, I argue for the need for a *global-local nexus* of institutions and processes, far beyond the scope of distant learning devices. This is even more needed since the pleading to go beyond techno-nationalism should not be misinterpreted as a plead for a global rationality in the sense of restraining the democratic will of governments that do not comply by the rules of capitalist globalization. As business has gone global, policies should go global too, in the sense that if policies really go global (i.e. in the sense that they will be reflecting democratic will) they will inevitably have to regulate the ways the private sector is acting globally.

The issues above bring necessarily the need to keep considering the key role **human resources** do play in science and innovation policies at large. For example, when viewed from the perspective of a single nation, immigration has been a critical path for increasing the supply of highly skilled scientists and researchers. Following again Bernanke (2011), the technological leadership of the United States (as well as the United Kingdom, and many other industrialized countries and regions) was and continues to be built in substantial part on the contributions of foreign-born scientists and engineers, both permanent immigrants and those staying in the country only for a time. And, contrary to the notion that highly trained and talented immigrants displace native-born workers in the labor market, scientists and other highly trained professionals who come to the United States tend to enhance the productivity and employment opportunities of those already here, reflecting gains from interaction and cooperation and from the development of critical masses of researchers in technical areas. More generally, lowering national barriers to international scientific cooperation and collaboration would enhance technological progress and innovation around the world, but it requires balancing brain circulation and migratory flows of skilled people.

The issue is certainly how far we all take advantage of opportunities that arise with the increasingly dynamic and globally distributed geography of innovation, as well as how it fosters a new global order and help others to use similar advantages at local levels.

This is because one must take up the challenge of probing deeper into the relationships between knowledge and the development of our societies at a global scale. Our inspiration comes from, among others, the seminal work of Lundvall and Johnson[12], who challenge the commonplace by introducing the simple, but powerful, idea of learning. Lundvall and Johnson speak of a "learning economy", not of a "knowledge economy". The fundamental difference is to do with a dynamic perspective. In their view, some knowledge does indeed become more important, but some also becomes less important. There is both knowledge creation and knowledge destruction. By forcing us to look at the process, rather than the mere accumulation of knowledge, they add a dimension that makes the discussion more complex and more uncertain, but also more interesting and intellectually fertile in an international context[13].

This closely follows the lessons Eric von Hippel, at MIT, has provided in recent years based on the American experience that user-centered innovation is a powerful and general

[10] Hepburn, D. (2011), "Mapping the World's Changing Industrial Landscape", *The World's Industrial Transformation Series*, IE WIT BP 2011/01, *Chatham House*, July 2011.

[11] Ghani, E., Kharas, H. (2010), "The Service Revolution", *Economic Premise, The World Bank*, May 2010

[12] B.-Å. Lundvall and B. Johnson (1994), "The Learning Economy", *Journal of Industry Studies*, 1/2: 23-42.

[13] Lundvall, B.A: (2011), "The Changing Global Knowledge Landscape and the Need for a Transatlantic Vision and a New Pragmatism", Aalborg University

phenomenon. It is based on the fact that users of products and services - both firms and individual consumers - are increasingly able to innovate for themselves. It is clear that this is growing rapidly due to continuing advances in computing and communication technologies and is becoming both an important rival to and an important feedstock for manufacturer-centered innovation in many fields.

Eric von Hippel has also shown that the trend toward democratization of innovation applies to information products such as software and also to physical products, and is being driven by two related technical trends: first, the steadily improving design capabilities (i.e., innovation toolkits) that advances in computer hardware and software give to users; and second, the steadily improving ability of individual users to combine and coordinate their innovation-related efforts via new communication media such as the Internet.

In other words, beyond suitable technical infrastructure, the process of "democratization of innovation" at a global scale requires people with the ability to engage in knowledge-based networks without borders. It is about people and knowledge beyond national borders, and this constant interaction has gained particular importance in recent years.

It is clear that the emerging patterns of innovation require new perspectives for public policies, which in mots ECD countries have increasing relied on traditional economic perspectives.

Certainly we need to move on from those days and consider better ways to integrate policies, as well as to diversify them at a global. A potential way to achieve this is to avoid overemphasizing current rivals sectors and competitive strategies, but rather to look at science, education and innovation policies towards new challenges that require a strong collaborative and pre-competitive approach.

Long-term challenges, namely those with current direct implications for US and EU firms (large and small), researchers and universities include the emerging opportunities associated with the democratization of human genome sequencing and the emergence of personalized medicine throughout the world, as well as the increasing convergence between heath sciences, physical sciences and engineering [14]. But also sustainable energy systems worldwide should be a subject of priority for government intervention and innovation policies with a great potential for global impact[15].

In this regard, and following the emerging discussion about the future of S&T, it is clear that, by and large, the financing of higher education and of science and innovation has occurred along rather traditional lines. Yet, the history of science is rich with varied means of financing science and technological innovation. More importantly, developments in the size, integration, and technologies available in global capital markets present the opportunity to think about new financing possibilities and processes of societal engagement in S&T policies. These involve moving from traditional, "one-way" (and most of the time fragmented) government policies, to integrated multi-stakeholder policies involving a wide range of public and private agents.

3. The scope for human-centered policy design

It has become a common place to refer human capital as critical condition for the creation and dissemination of knowledge in a way that striving towards greater human capital is of the utmost importance for any world region. This ultimate goal requires, per si, policies

[14] P. A. Sharp, M. A. Cooney, M. A. Kastner, J. Lees, R. Sasisekharan, M. A., Yafee, S. N. Bhatia, T. E. Jacks, D. A. Laufenburger, R. Langer, P. T. Hammond, and M. Sur, (2011), "The third revolution: The convergence of the life sciences, physical sciences, and engineering," tech. rep., Massachusetts Institute of Technology, 2011.

[15] Aghion, P., Julian Boulanger, J. and Cohen, E. (2011), "Rethinking Industrial Policy", Bruegel Policy Brief, June 2011

towards the renovation of higher education institutions, as well as for the expansion of the social basis for scientific and technological development and the appropriation of a scientific and technological culture. This underlines the need to further open-up access to higher education through various forms that take into account the experiences of people and non-linear life paths.

Science can have a major role in furthering the democratization of society through public policies that foster opportunities to access knowledge and the advanced training of human resources. **Broadening the social basis for higher education** promotes the qualification of the labour force and contributes decisively to social and economic development. The need to guarantee **higher education diversity, strengthening scientific institutions and investing in a strong science base**, is deemed as critical, but goes far beyond policies centered on innovation and industry-science relationships. It requires adequate training and attraction of skilled people, as well as promoting **scientific and technological culture among society**.

The growing demand for education and the prospects for its rapid evolution in the years to come is calling for the need to **better integrate science and education policies** in a way to further democratizing and promoting socio-economic development through two complementary goals:

1. Opening **access to the knowledge** base through higher education;
2. Promoting **advanced qualification of skilled people** and **strengthening research institutions** through adequate consideration of human resources and institutional issues in the process of technical change.

We argue this requires a better understanding of **diversity in higher education**, together with further democratizing access in general, and making it more socially balanced. In other words, this requires broadening the social basis for knowledge activities and strengthening the top of the research system leading to knowledge production at the highest level. Figure 1 shows schematically our main argument.

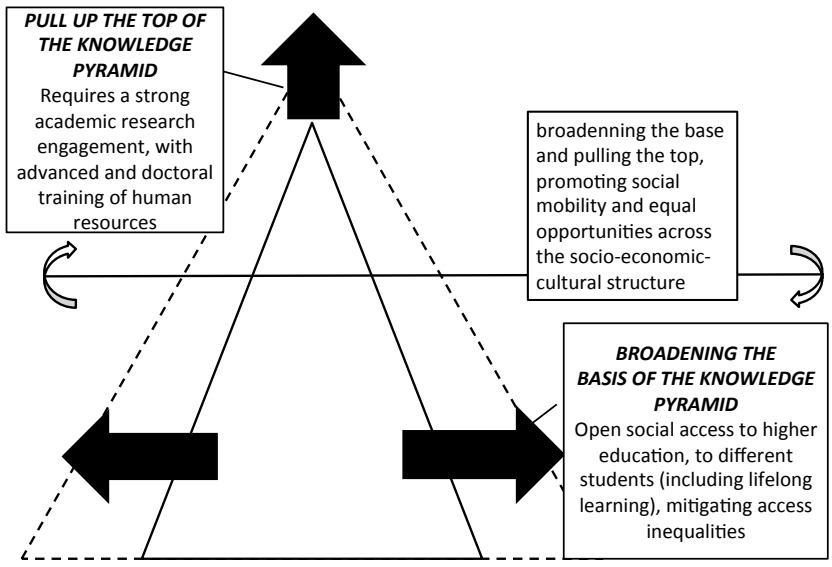

Figure 1 – Schematic representation of basic "orthogonal" policies to foster access and qualification, reducing scientific and knowledge gaps

In addition, our analysis has shown the success of such policies imply the densification of the knowledge landscape, with a diverse and enlarged institutional array, together with effective **institutional autonomy** and **integrity** of modern research higher education institutions in a context where innovation must be considered together with competence building and advanced training of people through the complex interactions between formal and informal qualifications. Beyond broadening the social basis for knowledge activities and strengthening the top of the research system leading to knowledge production at the highest level, this requires promoting intermediaries to guarantee active policies of knowledge translation and absorptive capacity.

Figure 2 shows schematically our main argument, extending the basic ideas of Figure 1 to consider extended "orthogonal" policies to foster access and qualification, together with institutional diversification through intermediaries promoting the densification of the knowledge landscape.

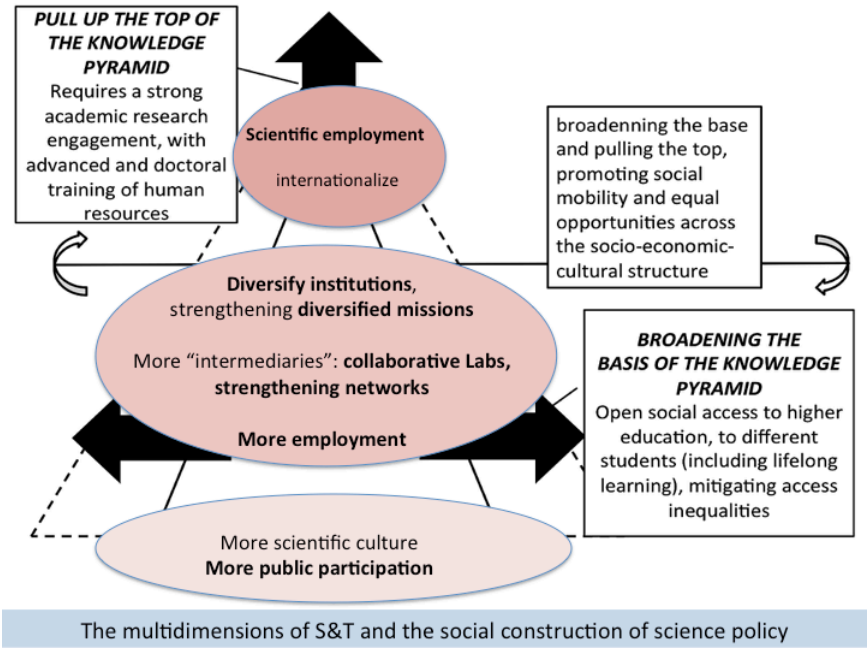

Figure 2 – Schematic representation of extended "orthogonal" policies to foster access and qualification, together with institutional diversification, through intermediaries promoting the densification of the knowledge landscape

This policy framework definitely requires a great attention of the **advanced qualification of skilled people and teaching staff** for the entire education system and its links with the economy and the entire society. This is a continuous process, evolving a long-time framework, requiring a proper understanding of the effective role played by science-university relationships, beyond the most "common places" and currently dominating policies of thinking science through short-term, demand-driven economic development issues. Our observation is also that effective **institutional autonomy and diversity of research and higher education systems** are to be promoted in a context where building human capital is a priority.

To cope with such a variety of demands and with a continuously changing environment, I argue that research and higher education institutions should continue to promote the necessary institutional integrity to facilitate students to experience environments of free knowledge production and diffusion. In internal organizational terms, this requires adaptable and resilient institutions. In public policy terms, by focusing governmental activity on human resources and on strengthening institutional autonomy, we require political actions to concentrate on critical pillars of democracy.

In other words, by focusing public policies on the "external" dimensions of knowledge institutions through attracting people and foster opportunities for knowledge production, governments and major public and private stakeholders are imposing higher education institutions to strengthen their capacity to make the critical internal changes for building and modernizing their systems of teaching and research within a path of diversity and specialization, without compromising quality.

Furthermore, by strengthening their institutional integrity together with enhancing their external links with society, higher education institutions are asked to carefully improve their relationships with economic, social and political actors, thereby creating "new" reinforced institutions that have gained societal trust.

4. Policy Implications: An experiential learning approach to research and education

Based on the pioneering work of Gibbons et al. (1994)[16] that originally introduced the ten shifts that universities would be facing in the future, this paper builds on recent research on the contemporary role of higher education, based on conceptual approaches to economic growth, including those in which the "accumulation of knowledge" is the fundamental driving force of long-term growth[17]. The process of knowledge accumulation is, however, complex, and requires continuous adaptation if the "places of inquiry" described by Burton Clark (1995)[18] are to be fostered.

In this paper we look at emerging paradigms guiding the development of higher education, with particular attention to new developments in emerging societies and developing regions and countries[19]. First, we argue that higher education institutions have to consider accommodating new configurations of knowledge production by establishing alliances with an increasingly large range of "knowledgeable" institutions[20]. Second, they need to secure and promote a sufficiently stable environment to train and supply talented people, including researchers for that increasingly large range of "knowledgeable" institutions. This leads to our main argument about the need, more relevant than never before, for systems and related public policies promoting effective institutional autonomy and integrity of modern higher education institutions (as defined by Conceição and Heitor, 1999[21] and also explored

16 Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M. (1994), The New Production of Knowledge- The Dynamics of Science and Research in Contemporary Societies, Sage Publishers.
17 Conceição, P., Heitor, M. V. (1999). "On the Role of the University in the Knowledge Economy", Science and Public Policy, 26(1), pp. 37-51.
18 Clark, B. (1995)."Places of Inquiry – Research and Advanced Education in Modern Universities", University of California Press, London.
19 See, for example, recent perspectives for development in J. T. Roberts and A. B. Hite (2007), "The globalization ad development reader", Blackwell Publ. Also, Katie Willis (2005), "Theories and practices of development", Routledge.
20 Nowotny, H., Scott, P., and Gibbons, M., (2001). Rethinking science: knowledge in an age of uncertainty. Cambridge: Polity.
21 Conceição, P. and Heitor, M.V. (1999), "On the role of the university in the knowledge-based economy". Science and Public Policy, 26 (1), pp. 37-51.

recently by Shapiro, 2005[22]), in a context where alliances and partnerships among universities worldwide, as well as between them and corporations, gain significant relevance[23].

The university, even in mass higher-education systems, continues to fulfill two basic functions that depend on it being a relatively stable institution. First, it remains the most important incubator of the next generation of researchers, and this do require effective "University-Science" relationships, because there is no other way to train researchers except in research-intensive environments. No other institution is so well equipped to undertake this task in modern societies (EC, 2011)[24]. But this function is gaining greater relevance through innovation and the need to secure and explore "University-Industry" relationships (D'Este and Patel, 2007)[25]. Among the most precious and valuable roles of the universities, is the supply and training of talented young people. Increasingly, this becomes one of the most essential contributions that universities are expected to make.

Second, is the university function of generating and promoting "cultural norms", which Nowotny et al. (2001) claim that the university should promote in both substantive and procedural terms. Nussbaum (1997)[26] is more ambitious and claims for the maintenance of a "culture of liberal rationality". Here we adapt and expand the notion explored by Conceição and Heitor (1999) that, at the starting of the twenty first century, universities should promote the necessary institutional integrity to facilitate students to experience environments of free knowledge production and diffusion. Again, no other institution is so well equipped to undertake this task in modern societies. For example, Conceição et al (2006)[27] explore this idea in terms of building "green campus" and making the university a "living laboratory" to better educate youngsters towards a sustainable society.

Our hypothesis is associated with the idea of "indwelling", firstly introduced by Polanyi[28] and recently explored by John Seely Brown[29] in terms of understanding learning through processes of knowing, playing and making. It also builds on Piaget's (1973)[30] view of knowledge construction by using "active methods which require that every new truth to be learned be rediscovered or at least reconstructed by the student", which has motivated Seymour Papert (1991)[31] to add the idea that knowledge construction "happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity"[32].

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22 Harold Shapiro (2005), "A larger sense of purpose – higher education and society", Princeton Univ. Press.
23 M. Heitor, "Global knowledge networks for inclusive growth or national systems of innovation?...is there a choice?", Technological Forecasting and Social Change, submitted for publication.
24 European Commission, "Mapping Exercise on Doctoral Training in Europe – towards a common approach", Report of the Working Group "Skills" to the Steering Committee on Human Resources and Mobility, June 2011
25 D'Este, P., and Patel, P., (2007), "University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry?", Research Policy, 36, 9, 1295-1313
26 M. Nussbaum (1997), "Cultivating Humanity: a classical defense of reform in liberal education", Cambridge, Harvard Univ. Press.
27 P. Conceição, J. Ehrenfeld, M. Heitor and P.S. Vieira (2006) 'Sustainable universities: fostering learning beyond environmental management systems', Int. J. Technology, Policy and Management, Vol. 6, No. 4, pp.413–440.
28 Polanyi, M. (1966). The Tacit Dimension. London, Routledge. (University of Chicago Press. 2009 reprint); See also, Polanyi, M. (1969), Knowing and Being. Edited with an introduction by Marjorie Grene. University of Chicago Press and (UK) Routledge and Kegan Paul.
29 John Seely Brown, Douglas Thomas, A New Culture of Learning: Cultivating the Imagination for a World of Constant Change, CreateSpace 2011.
30 Piaget, J. (1973), "To understand is to invent: the future of education", Grossman Publ., New York.
31 Papert, S. (1991), "Situating Constructionism", in Constructionism, Eds. I. Harel and S. Papert , Ablex Publ. Corp. Norwood, NJ.
32 See also, J. Bento, J. Duarte, M. Heitor and W. Mitchell (2001), Eds., "Collaborative Design and LEARNING: competence building for innovation", Quorum Books, Connecticut.

In other words, we are exploring an ancient Chinese idea:

> Explain it to me and I will forget
> Show it to me and I will remember
> Let me do it myself and I will understand it
> Lao-Tsé (-570 to -490)

This constructionism viewpoint facilitates the "new milieu of discovery, learning, and sharing" mentioned above, and our preliminary experiences suggest that it also facilitates to expose students to a multi-disciplinary experiences and prompt participants to built learning communities of students, faculty, and staff at many different and diversified levels of training[33].

Following the practices, skills, attitudes and values described by Horgen et al (1999)[34], among many other for process architecture, higher education must consider that learning a new practice requires moving through discovery, invention, and production not once, but many times, in different contexts and different combinations. Looking at many leading experiences worldwide in design process, we must realize that higher education has the potential to incorporate the humanities and social and physical sciences into a complex system of experiences. The objective is to integrate systems of knowledge and ways of practicing: "without knowledge, practice is limited and without practice, knowledge will never be fully realized".

The analysis calls for the need to strengthen the investment in research and education through adequate *institutional, spatial and international relational frameworks*, as presented in the following three sections.

4.1 Relational framework 1: institutional - Promoting institutional diversity and densification, with intermediaries and emerging stakeholders

We now turn to articulating innovation policies with key stakeholders and briefly address the role of ***intermediary institutions***.

This is because many international comparative assessments include specific recommendations towards launching major public programs to support and fund institutions of the type of the German´s Fraunhofer Institutes, the Dutch TNO, or the recently formed CATAPULT institutes in UK and the CARNOT Institutes in France, as well as many other similar institutions elsewhere. This remains to be better framed and understood, because all those institutions are very much framed in local and specific contexts, including direct relationship with specific national stakeholders.

Under this framework, a key issue that needs to be understood is that the processes that enable investments in R&D and human capital to be transformed into productivity gains are NOT a trivial matter everywhere. Specific policies and actions are needed to make this transition happen successfully.

The notion that intermediary institutions are the solution to many current policy questions may no longer suffice. New skills requiring intense and effective direct contact between

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33 S. Hasanefendic, M. Heitor and H. Horta (2016), "Training students for new jobs: the role of technical and vocational higher education and implications for science policy in Portugal", Technological Forecasting and Social Change, accepted for publication

34 Horgen, T.H., Michel, L.J., Porter, W.L. and Schon, D.A. (1999). "Excellence by Design – transforming workplace and work practice", John Wiley & Sons, Inc., New York.

advanced industries and different institutional stakeholders are essential and increasingly utilized. Linkages between different parts of the system will now require assimilating, sharing, acquiring and creating knowledge. Firms seek for access to knowledge in higher education institutions and research centers. Higher Education institutions, *per se*, search for collaborations, contracts and agreements from businesses. Students are employed and trained by industry. Entrepreneurs, innovative agents, knowledge producers, researchers, academics, and students are connected in a process of knowledge producing and sharing.

The challenges for policy are enormous and require new and adequate data sets. First, what can be done at the level of the political and regulatory systems to provide the necessary incentives to effectively elevate and broaden the overall level of technological leadership, as well as to foster absorptive capacity? Second, what can be done at the regional and national levels to establish and sustain international learning networks and trajectories that can lead to wealth creation and the required entrepreneurial capacity allied to new scientific competences and training needs?

To attempt answering these questions, we need to consider 'framework conditions', 'rules of the game' or 'institutions', depending upon the specific technical literature and how systems approaches are considered. Nevertheless, I would argue that emerging forms of technological change involves complex industry-science relationships, which include but do not seem to be confined to traditional forms of international commerce in services. This new model may derive its uniqueness from the very nature of the various parts to be involved. Beyond the continuous need to foster the integrity of academic communities, it looks very important to promote intermediaries (including engineering and technology centres over a range of different areas of knowledge) and technology-based firms. They act as critical players in potentially new forms of any innovation strategy.

The approach considered in this paper builds on two main lines of thought. First, large networks have been very interesting and relevant, but they are not effective in promoting change. Network competitiveness depends on many factors, requiring increasingly focused partnerships. Large international collaborative arrangements play an emerging role and should be promoted through new regulatory frameworks.

Second, the science and technology performance sectors – government, industry and academia – remain key players, but the connectivity links, and associations with other organizations are no less important. In particular, the increasingly relevant role played by intermediaries and technology-based firms is identified. These are also becoming global and require opening up science and innovation policies to multiple public and private agents and promoting global research networks towards socio-economic resilience. Above all, it requires framing future innovation policies in terms of the need to foster and promote a network of technology suppliers and skill-intensive employers.

Ultimately, the sustainable development of our societies requires a new phase of innovation policy that gives priority to skilled employment. Again, intermediaries and technology-based firms play a critical role in this process but require continuous incentives to better understand the advancement of professional activities.

The main policy implication of this observation is that inclusive innovation everywhere and anytime, together with the education and training of the labour force, is facing new challenges worldwide[35,36] as productivity growth and wealth creation needs to experience new boundaries[37]. For example, despite the efforts of national governments to foster

35 ILO (2015). World Employment and Social Outlook. 2015. Geneva: International labor office
36 ETUI. (2015). Benchmarking Working Europe 2015. Brussels: ETUI publishers
37 Schwab, K. (ed.). (2014). The Global Competitiveness Report 2014–2015. Geneva: World Economic Forum

regional innovation systems and to increase participation in higher education[38], almost two-thirds of the adult population in Europe is still lacking skills that would make them successful in innovation-driven environments[39]. These skills consist of a number of technical competencies and "soft" skills, including leadership, teamwork and efficient self-regulating competencies. The scarcity of this type of "skilled" labour force is not uniform and, for example, has been identified in many Southern European zones and other European peripheries, either in the service sector or in manufacturing[40].

The scarcity of skilled workers has often been attributed to, among other things, the considerable gap between educational systems and companies' needs, or to the fact that learning and training profiles are not suitable for current industry settings[41]. The relative mismatch between jobs and skills[42] has also been recently addressed by Osterman and Weaver[43] in the context of North America. The authors claimed that there is a need for "intermediaries", that is, institutions that can help match employer needs and training, and, at the same time, argued for the increasing relevance of non-university higher education.

We refer to technical, **professional and vocational higher education**, such as "Polytechnics" in Portugal, "Fachhochschulen" in Germany and Switzerland, "Hogescholen" in The Netherlands, or "Community Colleges" in US. The term "Universities of Applied Sciences", as it is also referred to in Europe, is not intentionally used to highlight the rationale for fostering diversification of higher education and for strengthening professional and vocational (i.e., non-university) higher education.

It should be noted that Australia and the United Kingdom abandoned a binary system in favor of a unified system of higher education and introduced forms of market competition in education, in order to produce a more diverse higher education system. The fact that the education market is not perfectly contestable and education is a positional good, explain the failure of these policies and the relative lack of specialization of their professional higher education.

For example, analysis of the Australian evidence shows that competition in a market environment type leads to stratification of the higher education system, with a relative emulation of the most prestigious research universities by the other institutions, instead of producing diversity at the institutional level[44]. The net result is that the less prestigious institutions, rather than seeking a diversified solution, tend to imitate the success of institutions in the search for financial rewards both.

Also Shattock[45], regarding the similar situation in the UK, notes that the attempt to use a competitive internal market in a period of rapid growth to give universities greater freedom to create more individualized missions did not succeed. The dominance of the cultural impact of research assessment exercises called research quality to the better funding discouraged the emergence of alternative models in a period of financial rigor.

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38 Hoidn, S. and K. Kärkkäinen (2014). Promoting skills for innovation in higher education: A literature review on the effectiveness of problem-based learning and of teaching behaviors. OECD Education Working Papers, No. 100. Paris: OECD Publishing.

39 OECD (2013). OECD Skills Outlook 2013: First Results from the Survey of Adult Skills. Paris: OECD Publishing.

40 van Ark, B., O'Mahony, M. and Timmer, M.P. (2008). The productivity gap between Europe and the United States: Trends and causes. Journal of Economic Perspectives, 22 (1), 25–44.

41 Tijdens, K.G., De Ruijter, J. and De Ruijter, E. (2012). Measuring work activities and skill requirements of occupations: Experiences from a European pilot study with a web-survey. European Journal of Training and Development, 36 (7), 751 - 763.

42 Hart, T. and Barratt, P. (2009). The employment of graduates in small and medium sized firms in England. People, Place and Policy Online, 3(1), 1-15.

43 Osterman, P. and Weaver, A. (2014) Skill and skill gaps in manufacturing. In Locke,R. and Wellhausen, R. (eds.), Production in the Innovation Economy, 17-50. Cambridge, Mass.: MIT Press.

44 Meek, L. (2014), Australian Academics, Teaching and Research: History, Vexed Issues and Potential Changes. Teaching and Research in Contemporary Higher Education. Springer.

45 Shattock, M. (2015), "UK university governance under stress", Intl. Higher Education Quarterly, 2015.

It should also be noted that, regarding the diversification of higher education, shaping the educational curricula in accordance with industry is, however, problematic (and often not recommended) since skill requirements are not easily definable. Approaching this issue requires a clear identification of relevant skills, rather than simply quantifying the skills of jobholders in a given occupational field. This calls for a common language between employers and training institutions and the development of intermediary functions in training institutions to match the educational supply with the needs of industry[46].

In addition, analysis suggests that strengthening problem-based learning and short-term project-oriented research through technical and vocational higher education can facilitate the process of training the workforce in skills of increasing relevance to local markets[47]. This can be facilitated if training is built around collaborative research, with external stakeholders engaged in the social and economic landscape of the regions under analysis. The process benefits from collaborative ties between the stakeholders and the practitioners of technical and vocational higher education, in particular when training is supplied together with a systematic engagement of ***practice-based research***.

Learning and training practices are increasingly research-based and, above all, inclusive of social and economic partners via formal and, most of the time, informal collaborative mechanisms. These occur, above all, as an opportunity for strategic action at organizational and content levels.

Overall, the need for a clear but synergistic *division of labour* at the regional and national levels among, universities, high-level vocational training encompassing research-based training, and industry and service businesses, stresses the idea of the "entrepreneurial university" referred to above in this paper was problematic because it worked if fact against the need of this institutional diversity. And the need to have this diversity at the regional and national levels is imperative if we want to avoid a world excessively segmented functionally, which necessarily leads to excessive social and territorial imbalances, inequalities and forced movements.

Again, the policy implications of these issues are enormous and should require the attention of the OCDE. For example, recent analysis in Europe[48] derived from initiatives to strengthen the research-teaching nexus in the *Hogescholen* sectors in Flandres and the Nederlands has identified three potential necessary conditions for policy making towards the modernization of technical and vocational higher education, if the external context and absorptive conditions are adequate:

i) The **human dimension** (it has always been relevant in any educational setting), particularly the specific role of human intermediaries supporting learning/research methodologies, and particularly Problem-based Learning approaches. This requires involving teachers and business experts, together with other social stakeholders and specific research staff, as the central elements of active learning systems;
ii) The **institutional research context** necessary to facilitate highly specialized knowledge, namely, in the form of *practice-based research* units that provide a professional context adequate to foster the necessary routines to collaborate with industry and society at high levels of specialization;

46 European Commission (2012a). New skills and jobs in Europe: Pathways Towards Full Employment. Brussels:Directorate-General for Research and Innovation
47 S. Hasanefendic, M. Heitor and H. Horta (2016), "Training students for new jobs: the role of technical and vocational higher education and implications for science policy in Portugal", Technological Forecasting and Social Change, accepted for publication
48 European Commission (2016), "Structural Higher Education Reform – Design and evaluation", Synthesis Report, April.

iii) The **external environment and funding conditions**, which do certainly depend on specific local and national ecosystems and are particularly influenced by the overall funding level for research and development in the regions considered.

The development of *professional practice based research* may be economy- or policy-driven but occur as an opportunity for strategic action at organizational and content levels. It may strengthen the institutional credibility of technical and vocational higher education by engaging local external actors in training the labour force. In addition, it may help to stimulate the necessary institutional and programmatic diversification of research and higher education systems.

4.2 Relational framework 2: spatial/local – turning the built environment in learning landscapes

Knowledge infrastructures, defined as the setting for knowledge production and including *university campi* and *science parks*, are a part of a small set of core institutions that have shaped western cities since their emergence as distinctive entities in early modern times[49,50].

Beyond the emerging trend worldwide of establishing knowledge infrastructures outside the city core in urban edges, facilitating new urban expansions[51], most of them have been conceived as autonomous entities, promoting the isolation of academic communities, highlighting ruptures within the urban fabric and originating unsustainable mobility patterns[52,53]. Thus, it makes sense revisiting the knowledge infrastructures concept, at a global scale, and build a new narrative towards "**knowledge-based urbanism**" as an emerging issue[54,55].

Although higher education *campi* have existed for more than 2000 years[56], including the very initial "Budhist learning centers" in India (namely in Taxila, 6th Century BC, in Nalanda, 3rd Century BC and Ajanta, 2nd Century BC) and at least since the 11th century in Islamic societies (namely with the creation of the Universities of Bagad and Nishapour in 1060 and, therefore, earlier than the creation of European universities in the 12th century), most of comprehensive and comparative overviews of the historical development of university design have been published with reference to two architectural models of the historical university[57,58].

Firstly, the "urban model", as represented by the University of Bologna, deeply anchored in the urban fabric and later followed by German Humboldtian-type universities, which spread through the cities occupying existent buildings. Secondly, its contrasting counterpart, the "Utopian model", as represented by the 19th century´s campus of the University of Virgínia, an autonomous entity, replicating an ambiance of calm combined with classical motifs and a

[49] Bender, T., ed. (1988). *The University and the City: From Medieval Origins to the Present*. New York: Oxford University Press.
50 Turner, P. V. (1984), "Campus – An American planning tradition", MIT Press, Cambridge.
51 Canas da Silva, L and Heitor, T. (2016) Campuses as sustainable urban engines. A morphological approach to campus social sustainability, 3rd World Symposium on Sustainable Development. Designing Tomorrow's Campus: Resiliency, Vulnerability, and Adaptation, Cambridge, MA USA
[52] Horowitz, H. (1987), "Campus Life", Afred Knopf Publ., New York
[53] Clark, H. (2002), Building education: the role of the physical environment in enhancing teaching and research. London: Institute of Education, University of London.
[54] See, for example, the UK experience: http://www.ncef.org/content/learning-landscapes-higher-education-final-report
55 Heitor, T. Nascimento, Tomé, A, R. Medeiros; V, (2013) (IN)ACCESSIBLE CAMPUS: Space syntax for universal design, Proceedings of the Ninth International Space Syntax Symposium Edited by Y O Kim, H T Park and K W Seo, Seoul: Sejong University, 2013
[56] Kanvinde, A. and Miller, H. J. (1969). "Campus design in India - experience of a developing nation", Printed by Jostens/American Yearbook Co., Topeka, Kansas, USA
[57] Edwards, B. (2000), "University Architecture", Spon Press, London
[58] Merlin, P. (1995), "L`urbanisme universitaire á l´etranger et en France", Presses de L´école Nationale des Ponte et Chaussées, Paris

ground plan that pays homage to classical antiquity and the legacy of Cambridge and Oxford in Britain or of Harvard, Yale and Princeton in North America[59].

Yet, neither model was particularly successful in shaping new knowledge infrastructures to accommodate studies and interaction with key stakeholders, in particular, in the fields of engineering and applied sciences, whose space requirements and building typologies of the historic models did not anticipate. Moreover, emerging opportunities and potential trends for technology-enabled active learning environments, including the way they are changing the traditional higher education *campi* concept, remain to be understood, namely in spatial terms[60].

Accompanying the expansion of higher education systems in the post-war period, knowledge infrastructures were established not only in, but also outside the city core and, above all, in urban edges[61,62]. A first knowledge infrastructures generation in the 1950's show the continuing influence of the ex-urban, Utopian model, and illustrates the conceptual affinity of such university *campi* with the design of "new national capitals", such as Brasilia and Chandigarh. Examples of this tendency include the new campus of Laval University, built in suburban Saint Foy, outside of Quebec City, the Simon Fraser University in Vancouver, or "Ilha do Fundão" in Rio de Janeiro, establishing minimum ties with the city. A second generation, includes those of ETH (Campus Hönggerberg) in Zurich, Switzerland, University of New South Wales in Sydney, Australia or Aalborg University in Denmark, among others. Although maintaining its self-sufficiency they tend to be highly accessible and identifiable, assuming prominent positions within the urban fabric.

Based on a reaction to the unsatisfactory results of functionalist thinking knowledge infrastructures and design[63], a third generation of *campi*, fully integrated within the urban fabric, seeks to realize and enhance preexisting and underlying social structures, as well as the human experience of higher education activities. This includes examples such as Freie Universität of Berlin, University of Melbourne, Universidad Nacional Autonoma de Mexico, in Mexico City, UCV – Universidad Central de Venezuela, in Caracas, and UnB – Universidade de Brasília, in Brasília.

Nevertheless, one may argue that no new models of university *campi* have been developed. Instead, a series of subtle modifications to the earlier models have been introduced, attempting in a few cases to foster a renewed relationship between the university and the city, with no clear boundaries such as Columbia University's master plan by Renzo Piano, the Bond University's campus opened in 1989 on Australia's Gold Coast, or the Docklands campus of the University of East London by Edward Cullinan Architects.

Research emphasizes the ambiguous and contingent role played by knowledge infrastructures in the process of urban development and regeneration and recognize that this role is not always explicitly incorporated into the strategy of the main urban agents and higher education stakeholders, as well as in planning decisions having in mind the changing role of government in territorial governance and spatial planning. Moreover, comparative studies on the performance of university *campi* and science parks planning and design in developing societies are scarce and most of the relevant literature reports specific cases,

[59] Thomas, G.E. and Brownlee, D. B. (2000), "Building America´s first university – An historical and architectural guide to The University of Pennsylvania", University of Pennsylvania Press, Philadelphia

[60] Chapman, M. P. (2006), "American Places – in search of the twenty-first century campus", American Council on Education, Praeger

[61] Sharpe, M.E. (2005), "The University as urban developer: case studies and analysis", Lincoln Int. of Land Policy., Cambridge, MA.

[62] Wiewel, W. and Perry, D.C. (2008), "Global Universities and Urban Development – Case studies and anaysis", Lincoln Int. of Land Policy., Cambridge, MA.

[63] Dober, R. P. (1996), "Campus Architecture – building in the groves of architecture", McGraw-Hill, New York

mostly under reference terms developed elsewhere and in relation to different socio-economic and cultural contexts.

On the other hand, policy research over the last two decades highlights the role of knowledge in economic and social developments, such as employment, housing, mobility, leisure and consumer activities[6465], and some authors suggested that research and higher education will become one of the main drivers of emerging economies in the next decades[66]. Silicon Valley, Boston's Route 128 and Cambridge in England are the typical examples mostly used to model success stories of the spatial and economic integration of knowledge infrastructures, although most of the times out-of-context.

In addition, by the time hundreds of new higher education *campi* are being planned and built in developing regions worldwide, the increasing democratization of higher education, student enrolment and diversity, and advances in technology[67], the spectrum and scope of knowledge-based environments are expected to continue to transform and evolve, putting pressure on knowledge infrastructures provision[68]

Also, the growing perceived evidence of potential benefits resulting from economic appropriation of results and methods of science by society, have changed the perception of "academic divide" or "scientific divide" and emphasizes the benefits of investing in knowledge infrastructures[69] and demand for governance and spatial strategies leading to effective higher education and research facilities-led regeneration processes.

In policy terms, one may ask: How far technology-enabled active learning environments are changing knowledge infrastructures and, in particular, higher education *campi* design? How far social and cultural requirements on the sustainability of future advanced learning environments should be further considered? How to ensure that these "knowledge-intensive edges" can mobilize and structure the "social construction" of cities, as well as to enable socially active and sustainable learning environments?

These questions are increasingly relevant because the physical campuses are evolving from "places for study" to "**places for leaning and interaction with knowledge**" becoming very vital and essential parts of cities and the territory, at large. In addition, decision making on campus management is getting more complicated by all the stakeholders involved, but is becoming more challenging as well[70]. Beside the opportunities that put higher education campuses in a broader and systemic context, there are threats. Campus buildings are aging, both technically and functionally, in need of reinvestment, while many developments cause more uncertainty in future space demand, making flexibility a necessity on building and campus level. How to replace top-down rigid blueprint plans with more adaptable policy and place-based approaches that encourage innovation and facilitation?

In other words, a new narrative of knowledge urbanism must consider exploring policies and practices that facilitate multi-objectives under diversified contexts[71], including:

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[64] Indovina, F. (1998). "Sinergi Tra Comunità e Università." *Archivio di Studi Urbani e Regionali* 60–61: 85–114.
[65] Barnett, R. and Temple, P. (2006), Impact on Space of Future Changes in Higher Education. UK Higher Education Space Management Project, for Space Management Group, 2006. Online www.smg.ac.uk/documents/FutureChangesInHE.pdf
[66] Ellsworth, E (2005), "Places of learning – media, architecture, pedagogy", Routledge, London.
[67] Mitchell, W. (2003), 'Designing the learning space'. *Campus technology, http://www.campustechnology/article.aspx?aid=39465*.
[68] Wagner, T. (2012), "Creating Innovators: The Maknowledge infrastructuresng of Young People Who Will Change the World", Scribner, New York.
[69] Thomas, D. and Brown, J.S. (2011), "A New Culture of Learning: Cultivating the Imagination for a world of constant change", New York.
70 Heijer (2008), "Managing the University campus in an urban perpspective: thery, challenges and lessons from the dutch experience"
[71] Kenney, D. R., Dumont, R. and Kenney, G. (2005), "Mission and Place: Strengthening Learning and Community Through Campus Design", American Council on Education, Praeger Series on Higher Education, Connecticut.

- Fostering the learning capacity of students in well-integrated knowledge infrastructures, by "balancing" an improved usage of technology-enabled active learning environments, social interaction and other traditional forms of "experiencing" knowledge infrastructures;
- Facilitating the presence of academics and places of learning in social and urban contexts and their interaction with key stakeholders, including companies, the labor force and the population at large;
- Preserving the uniqueness and spatial identity of knowledge infrastructures in a way to guarantee adequate places for the realm of learning and related intellectual activities.

Revisiting the concept of higher education *campi* and science parks in contemporary societies will help promoting cities as efficient and rich learning landscapes.

4.3 Relational framework 3: international – promoting global research networks

Looking at the present and tentatively forecasting the future, we argue that a new paradigm of international academic, scientific and technological cooperation that seems to be emerging as a major shaping factor for development at an unprecedented level.

Leading American research universities are playing a key role in this process worldwide, as a result of the accumulation of large investments in research and education over many decades until now. It should be clear that this is not a new issue. For example, Morgan (1979)[72] describes the role US universities played in helping to build an indigenous S&T base in developing countries until the 70´s and how far American Universities have engaged into that process. Some thirty years ago, Morgan recommended universities and policy makers about the future involvement on four areas: institutional building, cooperative R&D, resource base development, and education and training.

More recently this theme has been subject of various books and papers in the technical literature and, for example, the analysis of Bruce Johnstone[73], Altbach et al[74], as well as that of Knight[75], shows an active participation of US and EU universities in indigenous and local development practices, indicating related major advantages, as well as major challenges for them and national innovation policies in the near future. A recent report by the Royal Society of London further emphasizes these aspects in terms of scientific collaboration[76].

This emerging models of research and academic cooperation, that includes but do not seem to be hostage of the traditional forms of services' international commerce, may derive their uniqueness from the very nature of academic communities and from the strong meritocratic and universalistic ideals that prevail in science on an international scale. In addition, they are also driven by the flow of students and researchers, and by the citizen's sense of being part of a "mission" for scientific and social development that motivates some of the best professionals in academic and research institutions worldwide. However, under which conditions is such a model sustainable?

72 R.P. Morgan (1979), "Science and Technology for Development – the role of US Universities", Pergamon Press, New York.
73 D. Bruce Johnstone, Madeleine B. D'Ambrosio, and Paul J. Yaboski (2010). "Higher Education in a Global Society, Edward Elgar Publishing
74 Altbach, P., Reisberg, L., Rumbley, L.E., (2009), Trends in Global Higher Education: Tracking an Academic Revolution, Paris, UNESCO
75 Knight, J., (2011), "Education Hubs: A Fad, a Brand, an Innovation?", Journal of Studies in International Education, 15, 3, 221-240.
76 Royal Society (2011), "knowledge, networks and nations: global scientific collaboration in the 21st century", The Royal Society London.

To answer this question, Table 1 summarizes major lessons learned from **international research networks**[77]. It considers three major steps, including: i) people, mainly through education and training and including co-hiring of young researchers and exchange programs for faculty; ii) promote R&D through "test beds" and thematic networks, facilitating the integration of researchers and scientific institutions in international thematic networks with local relevance; and iii) institutional building, by adequate organizational conditions promoting the role of scientific institutions in society, their links with the private sector and adopting policies that foster the creation of critical mass, including those oriented towards fostering R&D consortia.

Table 1 - Potential guidelines to foster global research networks (Source: Heitor, 2015)

Major objectives and policy instruments	Justification
People Train, attract and co-hire researchers, fostering their exchange and the training of a teaching body	• Sustain excellence and internationalization in doctoral programmes • Foster and systematize the hiring of researchers with PhDs
Institutions Reinforce and promote the role of scientific institutions in society and their links with the economy and society	• Reinforce institutional evaluation mechanisms, in order to improve systemic and organizational efficiencies • Adopt policies that foster activities able to promote the creation of critical masses, including policies oriented towards fostering R&D consortia. • Promote the training of scientist, together with a new generation of technicians and other human resources to support R&D activities • Foster scientific and technological cultural in society
Incentives for R&D, Test beds and thematic networks Facilitate the integration of researchers and scientific institutions in international networks focused on "test beds", as living laboratories for the production and dissemination of knowledge with local relevance and facilitating ideas for markets worldwide	• Reinforce international partnerships and foster participation in international knowledge-based networks as a way to improve scientific quality and the employability of researchers • Foster S&T thematic networks in terms of test beds and living laboratories that can boost companies' capacity to export and access emerging markets.

It is under this context that innovation policies should help fostering a better understanding of future international collaborative paths in education, science and innovation. Ultimately, this will become a key issue for competitiveness everywhere.

Analyses of university-industry-government relations also show that structured international relationships may act as agents of change if associated with activities that are fundamentally different from the traditional role of universities, involving, most of the times, capacity building and various forms of social and economic appropriation of knowledge. They also require understanding the nature of international cooperation beyond the exporting/importing of "academic services" in all the institutions involved. In addition, they clearly break traditional boundaries of "national systems of innovation" and bring new challenges in terms of the necessary institutional integrity universities need to preserve and foster.

Again, we need to take stock of the diversity and evolution of university-industry-government relations and the way they are used to effectively increase the level of R&D expenditure and foster innovation.

[77] M. Heitor (2015), "How far university global partnerships may facilitate a new era of international affairs and foster political and economic relations?", Technological Forecasting and Social Change, 95, pp. 276-293.

5. Summary

This policy paper attempts to enlighten new insights in science, technology and innovation policy. It is aimed to contribute identifying main challenges and opportunities for policy making in order to better integrating education, research and innovation activities of higher education institutions (HEIs) and public research institutions (PRIs) to foster greater synergies and impacts from public investments in education and research at the local and global levels. Ultimately, it clarifies the increasing complexity of policies to foster private and public incentives to support R&D, but argues that emphasis should be given to the advanced qualification and employment of skilled human resources, emphasizing the role of "**learning by research**", together with adequate **institutional, spatial and international relational frameworks**.

In institutional terms, the need to promote risk-sharing partnerships among government, industry and academia oriented towards skilled employment suggest the increasingly relevant role played by intermediaries and calls for policies promoting **collaborative laboratories**. They should include a **wide diversity of research activities**, including "frontier and discovery research", the translation and diffusion of related knowledge (i.e., "translational research") and "professional practice based research" oriented towards the advancement of professional activities.

In spatial terms, the analysis calls for policy actions oriented towards turning the built environment associated to higher education and scientific campuses into **learning landscapes** to nurture and strengthen their relation with society and the economy through forms of collaborative learning spaces stimulating knowledge and innovation.

In international terms, the emergence of a new paradigm of **structured international higher education relationships** is emerging as shaped by a new era of government and industry intervention in association with knowledge. It calls for policy actions oriented towards global research networks.

In summary, I argue for the need to promote and integrate public and private strategies in modern societies fostering a non-hierarchical integration of formal policies and informal system linkages leading to knowledge-driven societies. This requires emphasizing the role of "**experiential learning**", together with opening-up science policies to multiple public and private agents and includes the continuous adaptation of systems of competence building and advanced studies, among which promoting global research networks should be highlighted.

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