Building Sustainable R&D Centers in Emerging Technology Regions

David Gibson, Jan Slovák
Editors

14th ICTPI

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Contents

Foreword

This collection of chapters has been focused on topics linked to the 14th International Conference on Technology Policy and Innovation[1] held at Masaryk University in September 2014. It has been my great honour and privilege to chair the local organization of the conference and to edit this book now.

I believe, the individual contributions also reflect the vibrant atmosphere of the Town of Brno, whose fast development in Education, Research and High-Tech Industry makes many Czech regions jealous. This was also the reason for the choice of the main theme of the conference and the title of this book – Building Sustainable R&D Centers in Emerging Technology Regions.

I am grateful to the Masaryk University and all our partners for the support and I am proud that we have established such a wonderful platform for high level international networking concerned with one of the hottest questions for regions like ours – how to build the sustainable Human Resources capacities for emerging large R&D Centres.

The reader might be also interested in the contributions to the conference programme split into four main tracks of the conference – Connectivity and cooperation; Education; Public policies and funding strategies: EU – national – regional; Smart Cities/Regions. The recorded contributions are available at:
http://ictpi2014.ctt.muni.cz.

Sincerely

Jan Slovák,
Technology Transfer Office,
Masaryk University

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1 The ICTPI Conferences are organized though a close partnership between the IC[2] Institute, The University of Texas at Austin, USA and the International Organizing Committee with participants from Centro Internacional de Inovação C2i, Curitiba, Brazil; Delft University of Technology, The Netherlands; Higher Schoolof Economics, Moscow, Russia; Zernike (UK) Limited, Cambridge, UK; EGADE, Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), Mexico; EMPI Business School, India; National Technical University, Athens, Greece; INESC, University of Porto, Portugal; Open University, Milton Keynes, UK; University of Tromsø, Norway; Institute of Federal Studies, National Research Council, Rome, Italy; LBJ School of Public Affairs, The University of Texas at Austin, USA; and The Center for Technology Transfer, University of Lodz, Poland; Technology Transfer Office, Masaryk University, Czech Republic.

As the creation, diffusion, and use of knowledge increasingly becomes a key strategic resource for regional as well as national economic development and social wellbeing, there is a need to enhance our understanding of the barriers and incentives for science and technology (S&T) knowledge generation, transfer, application, and diffusion in developed, developing, and emerging regions worldwide.

Since 1997, the main objective of the International Conference on Technology Policy and Innovation has been to bring together leading representatives of academic, business, and government sectors worldwide to present and discuss current and future issues of critical importance for using science and technology to foster economic development and social wellbeing locally and globally. Multidisciplinary perspectives are encouraged to provide state-of-the-art and useful knowledge to decision makers in both the private and public sectors – including up-to-date and effective education, business, and government policies and strategies. In this context, the 14th ICTPI Conference in Brno "Building Sustainable R&D Centers in Emerging Technology Regions" is focused on exploring opportunities, challenges, and policies related to capacity building in emerging technology regions.

I wish to thank conference organizers at the Technology Transfer Office, Masaryk University and regional and institutional partners from the South Moravian Region with special recognition to the Rector of Masaryk University Mikuláš Bek as well as local conference sponsors and the organizers namely Jan Slovák (Chair), Eva Janouškovcová, Markéta Vlasáková, Martin Bareš, Miroslav Mašek and Petra Nováková. I also thank members of ICTPI's International Organizing Committee representing 14 institutional and national participants. We all extend our appreciation to the conference keynote and other presenters and attendees and we very much enjoyed coming together to learn from each other, to get to know each other, and to better know the City of Brno and Masaryk University.

Sincerely

David Gibson,
IC^2 Institute,
The University of Texas at Austin,
ICTPI Chair

The Implementation of Applied R&D Centers in Brazil as a Strategy for Sustainable Industrial Growth: The case of the Institute of Applied R&D in Electrochemistry

Filipe Miguel Cassapo

Executive Manager of the International Innovation Center, Senai

web: http://www.senaipr.org.br
e-mail: filipe.cassapo@fiepr.org.br

Abstract

In 2011, the Federal Government of Brazil announced a bench of policies aimed at promoting the sustainable growth of the industry through innovation. These policies were composed by several instruments, such as tax reductions, subventions and low-rate financing of R&D, as well as investments in the creation of new national R&D centers. It is then in this very context that SENAI, The National Service for Industrial Apprenticeship of the Brazilian Industry System (the CNI – *Confederação Nacional das Indústrias*) signed in 2012 a technical cooperation agreement with BNDES (the National Bank of Development), consisting on a US$ 1 Billion loan for the implementation and

improvement of 26 applied research facilities, 59 technology transfer centers and 53 new professional education centers.

All the applied research centers which are then being developed are built based on the needs of the industry, taking into account not only present but also future technological challenges. Moreover, to ensure state-of-art R&D processes and infrastructure of the overall project, SENAI has nationally developed strategic agreements with the Massachusetts Institute of Technology (MIT – USA), and the Fraunhofer Society (Germany), in order to receive consulting and technical assistance in the implementation of its 26 research centers, as well as to develop join research activities.

In the context of this national R&D-based industry support project, the first of these Innovation Institutes to be inaugurated was the SENAI Innovation Institute in Electrochemistry, which was deployed in Curitiba, State of Paraná, in September 2013. The SENAI Innovation Institute in Electrochemistry has received from the BNDES a total investment of US$ 20 million for equipment and facilities. It is for the moment composed by an 8-members research team. The main research topics of this Institute of Innovation are: corrosion and coatings, electrochemical storage of energy, nanotechnology and new materials, electrochemical sensors, industrial productivity improvement and waste and effluent electrochemical treatment. This institute shall grow according to the development of industrial projects, and come to a 20-members research team until 2015.

All the institutes that have already been launched, as well as the ones to come, shall finally work as brokers between industrial needs and the offer of basic research of the Brazilian universities. They will therefore develop strategic partnerships with the academic sector in order to scale-up and apply research that may improve the productivity and sustainability of the industry.

Keywords

Brazil, National Innovation Strategy, Applied Research and Development, SENAI, Institutes of Innovation, Curitiba, Electrochemistry, Fraunhofer Society, Massachusetts Institute of Technology.

Introduction: The Challenges of Sustainable Industrial Development Acceleration in Brazil

Brazil is continental country. With the total area of 8.5 million square kilometers, it is the largest country in Latin America, and the 5th largest country in the world, both by area and by population. With 202 million inhabitants, Brazil is also a country of deep and harmonious cultural diversity. It is finally a country of responsible biodiversity, counting with the vast tropical forest of the Amazon Basin.

In economic terms, Brazil is the 7th highest GDP of the world, with US$ 2.4 trillion, although its nominal GDP per capita is only US$ 11 thousands, which sets the main economic challenge of this country: to rise quickly and efficiently productivity, and therefore competitiveness on a global scale, which shall allow Brazil to insert itself more definitively at the heart of global value chains, where high economic value is created through innovation-intensive processes and products.

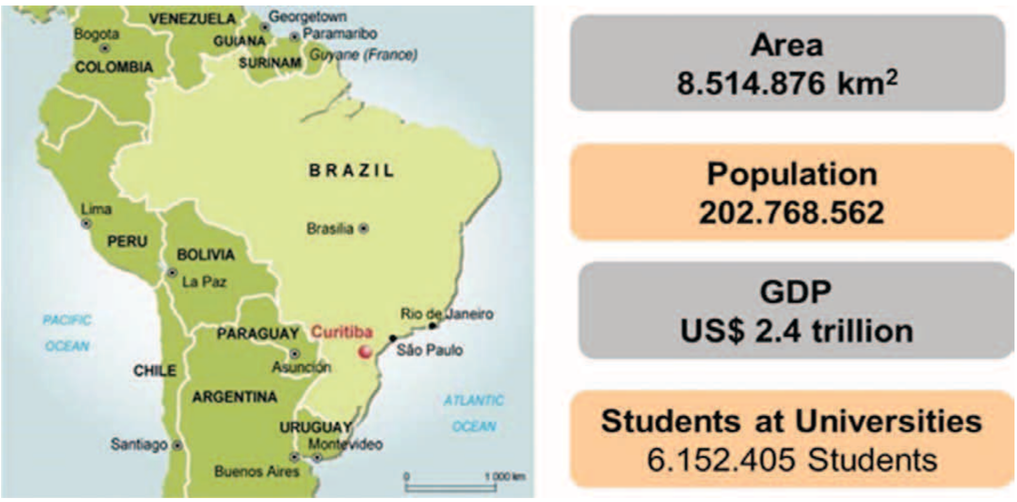

Figure 1: Brazil, a Continental Country. Data source: IMF – International Monetary Fund, Report for Selected Countries and Subjects

http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/weorept.aspx?pr.x=89&pry=7&sy=2012&ey=2019&scsm=1&ssd=1&sort=country&ds=.&br=1&c=223&s=NGPD %2CNGDPDPC %2CPPPGDP %2CPPPPC&grp=0&a, and INEP – Instituto Nacional de Estudos e Pesquisa Educacionais Anísio Teixeira, http://portal.inep.gov.br/visualizar/-/asset_publisher/6AhJ/content/matriculas-no-ensino-superior-crescem-3–8

When speaking about science, technology and innovation, some data allow us to understand where are the main challenges of the country, in order to raise the productivity of the industry. In terms of scientific production, Brazil is getting clause to 2.7 % of the world's paper production, indexed at Thomson/ISI. The growth of the generation of the Brazilian science, measured by referenced scientific production was of 616 % from 1996 to 2012, coming to 53.083 scientific papers indexed at Scopus in 2012, and putting Brazil at the 15th global position in terms scientific paper publication[1]. This constitutes of course a very good progress, and gives to Brazil the great opportunity of a quick growth, in terms of R&D-based economy.

There are of course other challenges, which go beyond science generation, in order to promote innovation. These challenges do actually arise when checking how this important and well developed Brazilian science is actually converted into industrial productivity. As it is well known, innovation is much more than science. It is strategic and continuous capability of converting science into economic wealth, through the development of knowledge-intensive products and processes. In that sense, the national investments in R&D&I represent presently in Brazil only 1.2 % of the GDP in 2012[2], which is of course much lower than what the developed countries, such the USA, Germany, Japan or South Korea invest. Actually, all these country involve more than 2.5 % of their GDPs in R&D&I activities. Another important data that has to remembered, in order to understand the real challenges of Brazil, in terms of R&D&I-based improvements of productivity, is the share of public versus private national investments in R&D&I. It is well known that all knowledge-intensive-economy countries have more private that public investments in R&D&I. For the moment, in Brazil, only 45 % of the total investments in R&D&I come from the private sector, meaning that Government, whether on a Federal or State level, is still the main protagonist when it comes to support innovation.

The economic consequences of this R&D&I-investment-landscape are of course almost obvious. Brazil still bases its growth on local market demands, and commodities-based exportation. When it comes to R&D&I-based products and services, Brazil is most of time, with of course some important exceptions, very initially inserted inside the global value chains. Therefore, in terms of Global Innovation Index, Brazil appeared in 2014 at the 61st global position with an index of 36.3[3]. In terms of patents generation, Brazil only had 254 conceded patents at the USPTO in 2013, whereas an intense R&D&I country such as South Korea was able to have 14.548 patents conceded this same year[4].

1 Source: MCTI – Ministry of Science Technology and Innovation, Brazil, Participação percentual do número de artigos brasileiros publicados em periódicos científicos indexados pela Thomson/ISI e Scopus em relação ao mundo, 1996–2012, http://www.mct.gov.br/index.php/content/view/5711/Participacao_percentual_do_numero_de_artigos_brasileiros_publicados_em_periodicos_cientificos_indexados_pela_ThomsonISI_e_Scopus_em_relacao_ao_mundo_1996_2012.html

2 Source: MCTI – Ministry of Science Technology and Innovation, Brazil: Dispêndio nacional em pesquisa e desenvolvimento (P&D) em relação ao produto interno bruto (PIB) por setor, 2000–2012, http://www.mct.gov.br/index.php/content/view/308855.html

3 The Global Innovation Index, 2014 country ranking, https://www.globalinnovationindex.org/content.aspx?page=data-analysis

4 Source: MCTI – Ministry of Science Technology and Innovation, Brazil, Pedidos e concessões de patentes de invenção junto ao Escritório Americano de Marcas e Patentes (USPTO, na sigla em inglês) de países selecionados, 1999–2013, http://www.mct.gov.br/index.php/content/view/346052.html

In order to accelerate its industrial knowledge-based development, Brazil therefore needs to strengthen its R&D&I-based private activities, and to do so, it needs raise effectively and quickly its R&D&I-GPD investment ratio, mostly through the private sector. This of course requires a national Science, Technology and Innovation Strategy, with new mechanisms that shall foster the transfer of technology from the universities to the businesses.

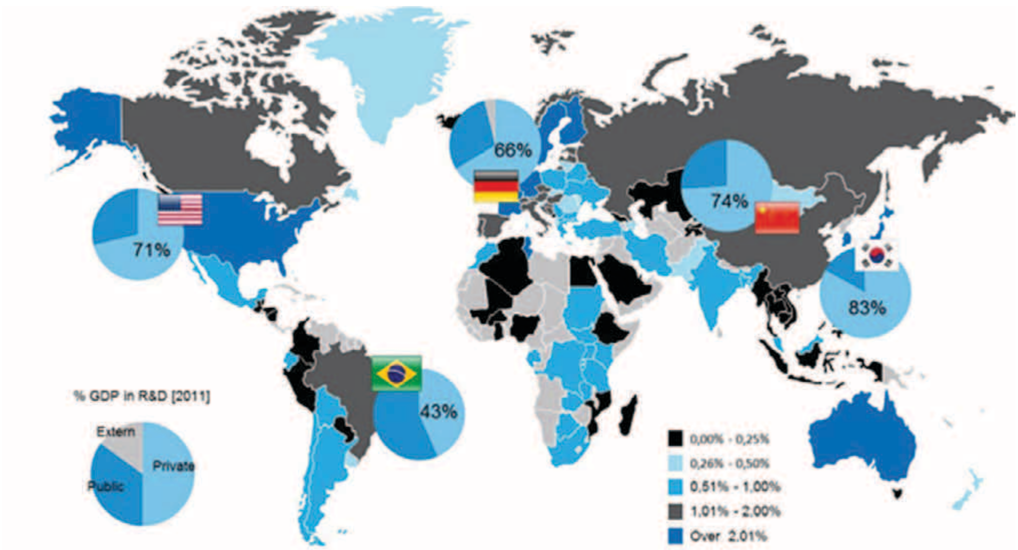

Figure 2: The Brazilian Industrial Development Challenge, improvement of R&D&I Investments, Source: Unesco; Roland Berger Strategy Consultants; Eurostat; OECD

The Brazilian National Science, Technology and Innovation Strategy

In order to address the challenges of developing a deeper R&D&I-based economy, the Federal Government of Brazil announced 2011 a bench of policies aimed at promoting the sustainable growth of the industry through innovation. This is the so-called "Brasil Maior" Plan[5], which was composed by several instruments, such as tax reductions for the companies that invest in local R&D activities, subventions and low-rate financing of R&D activities inside companies, lower tax rate in strategic sectors, investments in the creation of new national R&D centers, and new financing instruments for supporting industrial exportation. The "Brasil Maior" Plan itself derives as an operational plan from the so-called National Science, Technology and Innovation Strategy (ENCTI – Estratégia

5 Further information can be found at http://www.brasilmaior.mdic.gov.br/

Nacional de Ciencia, Tecnologia e Inovação[6]). This overall strategy defines science, technology and innovation as a priority for the development of Brazil, and aims at consolidating and expanding Brazil inside the knowledge-based economy, through the promotion of innovation inside the private sector, with new human resources development policies, as well as new financing instruments for applied R&D&I in the country. The main performance indicator of this strategy is of course R&D&I-PIB investments ratio, which shall come to 1.8 %, with at least 0.9 % of investments from the private sector. Another important indicator is the total number of private companies that will perform continuous R&D&I activities, which shall grow from 3.425 in 2008 to 5.000 in 2014, according to the survey realized by IBGE (Instituto Brasileiro de Geografia e Estatística, the Brazilian Institute of Geography and Statistics) called PINTEC [7](Pesquisa de Inovação Tecnologica, the National Technological Innovation Survey).

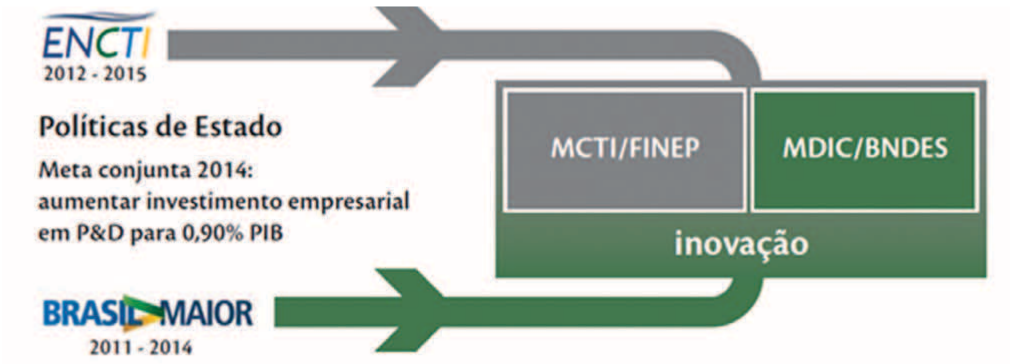

Figure 3: Brazilian National ST&I Strategy, Source: MCTI – Ministry of Science Technology and Innovation, Brazil

According to the Brazilian Ministry of Science, Technology and Innovation, the ENCTI strategy shall represent a total package of US$ 37 Billion (R$ 74.6 Billion) available between 2012 and 2015 to support R&D&I activities, both an academic and private perspective. Most of this investment shall come from this Ministry (39.1 %).

6 Further information on the ENCTI (Estratégia Nacional de Ciencia, Tecnologia e Inovação) can be found at http://www.mct.gov.br/upd_blob/0218/218981.pdf

7 The data of the PINTECsurvey can be found at http://www.pintec.ibge.gov.br/

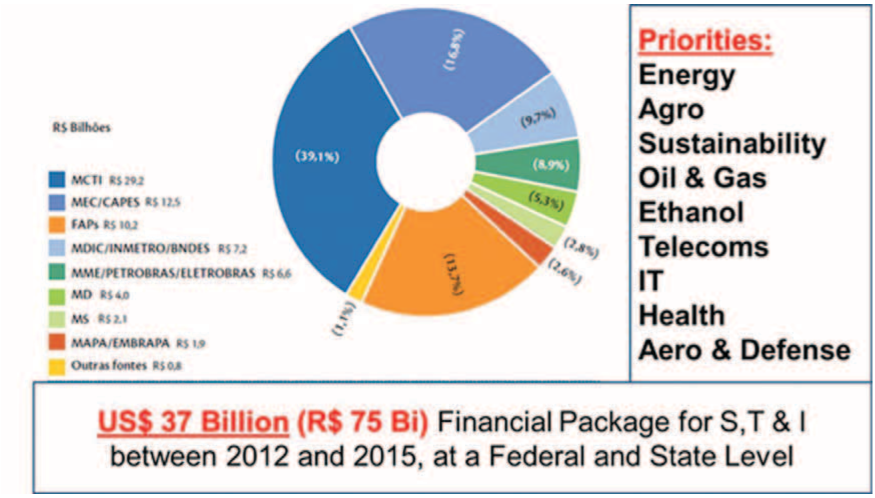

Figure 4: Federal and State Public Funding for ST&I in Brazil (2012–2015), Source: Consetci, Conselho Nacional de Secretários Estaduais para Assuntos de C&T&I
http://www.consecti.org.br/wp-content/uploads/2012/03/mcti_elias_consecti_confap_08_de_marco_curitiba.pdf

Two major instruments shall be remembered in order to understand the context of this knowledge-based industrial growth strategy:

- The so-called "Inova Empresa[8]" Plan of the National Development Bank of Brazil (BNDES, http://www.bndes.gov.br/) and,
- The Brazilian Company of Industrial Research and Innovation (Embrapii, http://embrapii.org.br/).

In a few words, "Inova Empresa" consists on a US$ 15 Billion package of the Federal Government, which aims at supporting Innovation and R&D activities directly inside of industrial enterprises. It is composed by three types of instruments: economic subvention (non-refundable) for early-stage R&D activities, call for projects for Public-Research-Institution-Private-Company cooperation, and Public-Private-Partnership for R&D-based activities.

As a complement, the Embrapii, the Brazilian Company of Industrial Research and Innovation, consists on a networked R&D public company, which gathers a group of applied research centers across the country that receives financial support of the Federal Government in order to perform applied R&D projects inside industrial enterprises.

8 Further information on the "Inova Empresa" plan can be found at the BNDES website, http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Plano_inova_empresa/

The model used by Embrapii is based on the German Fraunhofer Society approach, where 1/3 of the investment in a given R&D project performed inside a company is supported by non-refundable Federal Government incentive, 1/3 is paid directly by the client-private-company, and 1/3 shall be provided by the applied R&D center which will conduct the project, through own counterparts, or competitive R&D funding from national call for projects.

One last and still important R&D&I-incitement policy, which was actually the first one to be established in 2006 is the so-called fiscal benefits of the Federal Innovation act. This federal regulation allows companies with specific characteristics to reduce federal tax payment, until a certain boundary, according to the proven investments realized by this company in R&D&I activities. On a practical point of view, the total amount of companies which does effectively benefit from tax reduction through this program has grown quite slowly, and represents 787 enterprises in 2012, most concentrated in the south and south-east regions of Brazil.

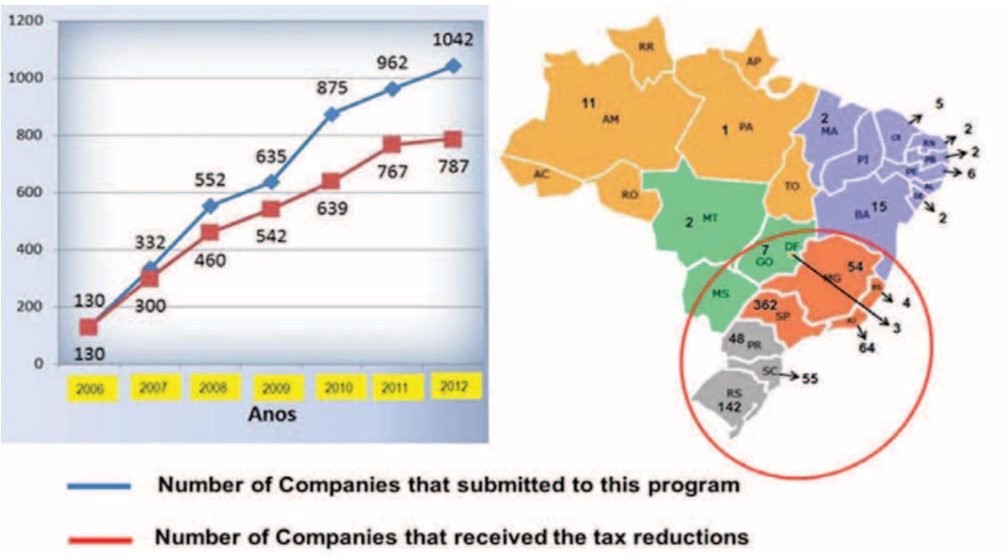

Figure 5: The Innovation Act Program Impact since its creation (2006–2012), Source, Ministry of Science, Technology and Innovation, Brazil, Relatório Annual da Utilização dos Incentivos Fiscais
http://www.mct.gov.br/upd_blob/0229/229781.pdf

Within this overall new context for Science, Technology and Innovation, a tremendous opportunity emerges for addressing the competitiveness challenge of the Brazilian Industry, inserting companies into high-added-value global chains. Such a possibility does of course require the creation of new applied R&D interfaces, which shall improve the academy-enterprises relationship processes, and operate continuously and systematically the required technology transfer to the private sector. This is where SENAI, the National Service of Industrial Apprenticeship, the major private network of professional education and technological services in Brazil, will join the stage, and initiate the implementation of a large applied research and development labs and technology transfer facilities network.

The National Industrial Research and Development Program of SENAI

Founded in January 1942 to support Brazil's industrial development based on import substitution and supply the need for qualified labor, SENAI is now a very traditional and respected industrialization-support institution in Brazil. SENAI's mission consists therefore on promoting vocational and technological education, innovation and industrial technology transfer, in order to contribute to the increase of the Brazilian industry's competitiveness. With over 20.000 employees all across Brazil, it is the largest private network of professional education and technological services in the country. SENAI counts with more than 810 schools and technological center, and more than 4 million technical schools enrollments in 2014[9].

SENAI is therefore very well known, and deeply recognized among the industry as a pragmatic partner for productivity and competitiveness increase. With its natural connection with education and technology, due to its long tradition in technological services and professional schools, it was a natural further step for SENAI to go deeper into productivity support, by upgrading some of its technological units into applied R&D&I facilities and technology transfer centers, as well as expanding its national network with new research labs.

It is then in this very context that SENAI signed in 2012 a technical cooperation agreement with BNDES, the National Development Bank of Brazil. This cooperation consisted on a US$ 1 Billion loan for the implementation and improvement of:

- 26 applied research facilities, called "ISIs – Institutos SENAI de Inovação", *SENAI Innovation Institutes,*
- 59 Technology Transfer Centers, called "ISTs – Institutos SENAI de Tecnologia", *SENAI Technology Institutes, and,*
- 53 new professional education centers, called "CFPs – Centros de Formação Profissional, *SENAI Professional Education Centers.*

9 Further facts and data on SENAI can be found at http://www.portaldaindustria.com.br/estatisticas/ http://www.portaldaindustria.com.br/estatisticas/

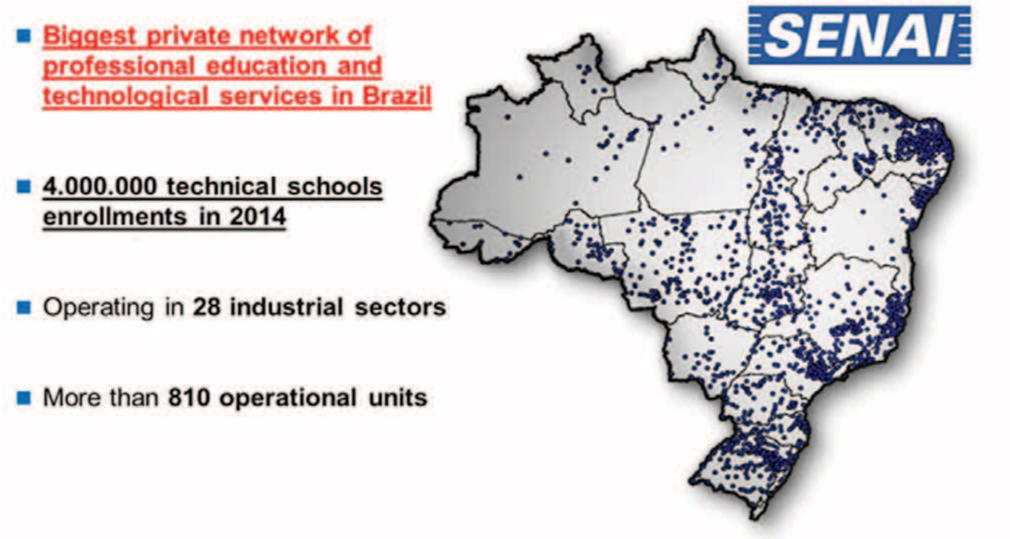

Figure 6: The Presence of SENAI in Brazil: Facts and Data.
Source: SENAI, the National Service of Industrial Apprenticeship
http://www.portaldaindustria.com.br/estatisticas/

Based on the successful approach of the Fraunhofer Society, in Germany, SENAI decided in 2012 to implement 26 institutes of applied research and development, which shall exactly operate on a pre-competitive scale, addressing real productive challenges of the Industry with the development of new knowledge-intensive technologies. In order to do so, these institutes have then been built based on real competitive needs of interviewed industries, and possess the structural, human and relation capital needed to fulfil their missions. Structural capital is composed by the applied research and development facilities required to perform applied research project for private companies. Human capital consists on the proper PhDs and MScs workforce of the institutes, which shall be properly prepared and trained to perform applied research projects. Finally, relation capital is the institutional and human relation that these institutes shall develop with the so-called triple-helix of innovation, that is, the universities, where new knowledge is created, the Federal and State governments, where S&T&I policies are developed, and incentives granted, and of course the private industries, the main clients of these SENAI Innovation Institutes.

The strategy chosen by SENAI consists therefore on covering all present and potential applied research needs of companies with a network of 26 technology-oriented institutes, which will deal with themes as different as renewable energies, mineral technologies, logistics, applied chemistry, laser or polymer engineering. From the 26 R&D institutes that shall be operational until 2016, 4 have already been inaugurated, and 11 are in final phase of implementation.

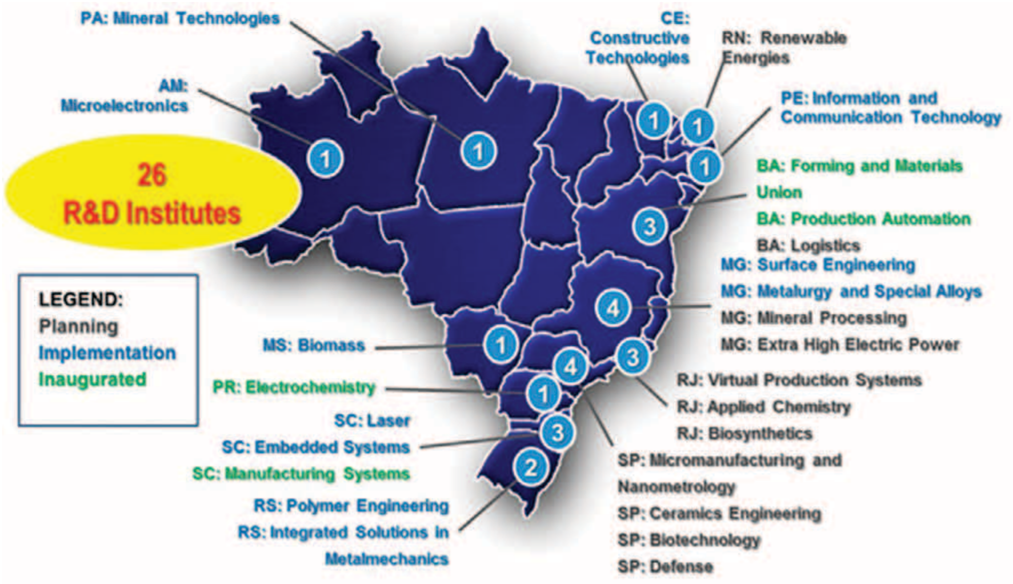

Figure 7: The Location and Focus of the 26 Applied R&D&I Institutes of SENAI in Brazil, Source: Programa de Apoio à Competitividade da Indústria
http://www.portaldaindustria.com.br/senai/iniciativas-senai/programas/programa-senai-de-apoio-a-competitividade/2012/06/1,3956/institutos-de-inovacao.html

To ensure state-of-art R&D processes and infrastructure of these research centers, SENAI has developed agreements with the Massachusetts Institute of Technology (MIT – USA), and the Fraunhofer Society (Germany), in order to receive consulting and technical assistance for their implementation, as well as to develop join research activities. Monthly workshops have then been conducted with Fraunhofer since 2012 in order to continuously improve the vision of a national applied R&D network of SENAI in Brazil.

In complement of these 26 applied R&D facilities, an additional network of 59 technology transfer centers is being implemented at the same time. The main idea of these complementary institutes is to perform laboratory tests and productive process improvements, based on the innovative technologies that will be developed by the Innovation Institutes of SENAI. The operational domains of this second network of institutes are of course even broader, and open the research topics of the first network into more industry-oriented specialization.

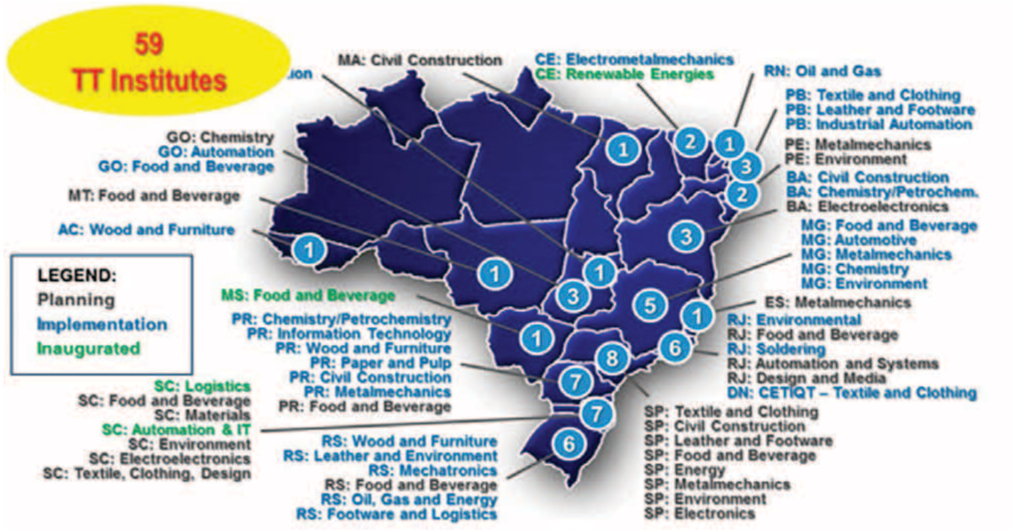

Figure 7: The Location and Focus of the 59 Technology Transfer Institutes of SENAI in Brazil, Source: Programa de Apoio à Competitividade da Indústria

http://www.portaldaindustria.com.br/senai/iniciativas-senai/programas/programa-senai-de-apoio-a-competitividade/2012/06/1,3954/institutos-de-tecnologia.html

This overall project, which aims at strengthening the industry through SENAI new R&D activities as well as entrepreneur technical and technological education, started in 2013 and shall be fully deployed in 2016. The first results are already emerging, with the implementation and concrete applied R&D operation of some institutes. This is in particular the case of the SENAI Innovation Institute in Electrochemistry, located in Curitiba, Paraná.

The Innovation Ecosystem of SENAI in Paraná, and the SENAI Innovation Institute in Electrochemistry

One of the most intensive R&D-oriented regions in Brazil is the southern state of Paraná, which borders the states of São Paulo, Santa Catarina and Mato Grosso do Sul, and even Argentina, where huge demand for applied R&D is present. Paraná has an excellent infrastructure of roads, airports, railways, ports and power plants. The state economy is the fifth largest in the country and now accounts for 9 % of national GDP, registering a per capita income of R$ 21.600 in 2010, far above the average value for Brazil. According to a study of the Development Sector of the Federation of Industries of the State of Paraná in 2012, the main segments where applied R&D is required in this State are:

- Oil, Gas and Energy,
- Metal Working,

- Chemical Industries,
- Mining,
- Automotive, and,
- Civil Construction

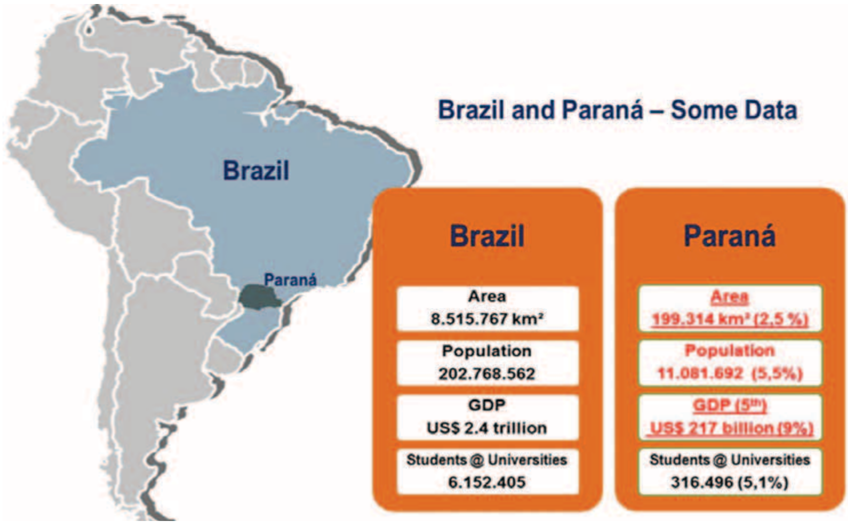

Figure 8: Macro-Economic position of the State of Paraná in Brazil, Source: Observatório das Indústria, O Paraná em Dados
http://www.fiepr.org.br/observatorios/uploadAddress/Parana_em_Dados[48397].pdf

It is therefore in Curitiba, the Capital of the state of Paraná, that the first of the 26 Innovation Institute of SENAI has been inaugurated. The Innovation Institute of SENAI Paraná in Curitiba was deployed in September 2013, and is specialized in Electrochemistry.

This applied R&D facility has been strategically inserted inside one of the major innovation territory of the country, the so-called "Industry Campus[10]". The Industry Campus consists on an innovation ecosystem which is being developed all together with the State Government, the universities and research centers of the State, investments funds and venture capitalists, startups incubators, the Industry, and of course the Federation of Industries of the State of Paraná. In a 20 Km² surface, the Industry Campus gathers most of the PhDs and MScs students of the State, from the major universities such as the Federal University, the Technological University and the Catholic University. It is therefore a strategic territory to be converted into an applied research and technology transfer spot.

10 More information can be found at: http://www.sistemafiep.org.br/campusdaindustria/

Figure 10: Urban View of the Innovation Ecosystem of the "Industry Campus"

It is then at the heart of this innovation ecosystem that the 1st applied R&D center of SENAI has been launched in 2013. This SENAI Institute of Innovation is focused on applied research activities in electrochemistry. Its main research topics are: corrosion and coatings, electrochemical storage of energy (fuel cells, batteries), nanotechnology and new materials (nanostructured materials, biomaterials, and ceramics), electrochemical sensors (for human and animal health purposes, and industrial productivity improvement) and waste and effluent electrochemical treatment.

The SENAI Innovation Institute in Electrochemistry has received from BNDES a total investment of US$ 20 million for equipment and facilities. It is for the moment composed by an 8-members research team. This institute shall grow according to the development of industrial projects, and come to a 20-members research team until the end of 2015. This applied research center was built based on the needs of the industry, taking into account not only present but also future technological challenges. It finally works also as a broker between industrial needs and the offer of basic research of the Brazilian universities, and therefore develops strategic partnerships with the academic sector in order to scale-up and apply research that may improve the productivity of the industry. It is of course a direct answer to the Federal Government movements of Inova Empresa and Embrapii, which aims at improving the sustainability, the competitiveness and the productivity of the Brazilian industrial sector.

The inauguration of this SENAI Innovation Institute in electrochemistry was the opportunity of realizing the 1st International Seminar on Industrial Innovation in Electrochemistry[11], which gathered industrial companies as well as applied research centers from different countries (such as the USA, Germany, Canada, the UK, and of course Brazil) in order to debate the challenges of applied research and development in emerging and in developed countries.

Figure 11: The SENAI Innovation Institute in Electrochemistry, State-of-Art Applied R&D Facilities

In order to fully attain the mission and vision of the Electrochemistry Innovation Institute, the following main service areas are being developed, in response to the identified industrial demand and the future requirements regarding Electrochemistry technology innovation:

- Analysis of corrosion
- Optimization of chemical processes
- Treatment of corrosion / coatings
- Testing and development of battery technologies
- Electrochemical sensors
- Applied R&D skills development in Electrochemistry
- Effective and efficient waste treatment

11 More information can be found at http://blucherproceedings.com.br/issues/details/37

Several equipment and laboratory planning workshops have been conducted with national and international experts. As a result, a strategic understanding of the human and structural capital needed for this Innovation Institute was developed in 2 phases: Phase 1 (from 1st semester 2013 to 1st semester 2015): 300 square meters of the already available facilities of SENAI in Paraná at the Industry Campus will be adapted, in order to setup the main equipment that is required to start the applied R&D in Electrochemistry operation.

Phase 2 (from 1st semester 2013 to 1st semester 2015): a simultaneous construction of a new building with 9.950 m^2 will be realized in order to set up the equipment that has temporarily been installed and all remaining research equipment upon completion.

Facilities for Electrochemistry Applied Research	
Electrochemical characterization	**Research and Analysis**
Spectrometry laboratory	Electrochemistry laboratory
Metallography laboratory	Artificial weathering laboratory
Bio-corrosion characterization laboratory	Sensor development laboratory
Microscopy laboratory 1	Battery development and test laboratory
Microscopy laboratory 2	Painting and surface treatment laboratory
	Solid-waste and waste-water treatment laboratory
	Scale-up laboratory
Facilities for Innovation Management and Applied Research Skills Development	
7 research areas, a complete support space	
8 research-skills development areas and two libraries	
5 auxiliary-laboratories for applied R&D Skills development, 2 lecture halls, 8 client meeting rooms, 1 consultancy open-space	
2 major auditoriums, 10 new business incubation and innovation partnerships rooms	

Figure 12: Facilities of the SENAI Innovation Institute in Electrochemistry

Main Research and Development Activities	Operated Equipment
Electrochemical Characterization	
Concentration determination of ion metals for corrosion, batteries, electro-deposition, and sensors applications	Atomic absorption, carbon-sulfur analyzer, furnace
Microstructure analysis, inter-granular for metallic corrosion investigations	Inverted Metallographic Optical Microscope, Digital Hardness, tester, polishing equipment, electrolytic polishing equipment
Culture medium preparation for bacteria, fungi and algae for corrosion studies	Autoclave, PCR Thermo Cyclers, Incubator for BOD, bio-film sensor
Surface analysis for corrosion, sensors, batteries and bio-corrosion investigations, characterization of surface products and chemical elements	Scanning Electron Microscopy, Atomic Force Microscopy, Infra-Red Spectroscopy, Raman Spectroscopic
Micro-structural studies of substrate and compounds characterization for corrosion, sensors, batteries, bio-corrosion investigations	X-Ray Diffraction, X-Ray Fluorescence
Research and Analysis Laboratories	
Research in interfaces phenomena such as corrosion, bio-corrosion, electrodeposition, surface treatment. Activities: R&D, standard tests, consulting for industrial sector, training courses	Potentiostat / galvanostat, bipotentiostat, workstation combining potentiostat and microscopy for electrochemical investigations, reactor
Accelerated aging tests of metallic, polymeric and painted samples	Salt spray chamber, humidity chamber, UV chamber, whether-o-meter chamber
Research and development of sensors for general applications, like gas-, humidity-, electrochemical sensors for industrial processes control and monitoring	Digital scanning potentiostat / galvanostat bi-potentiostat
Investigations in lead acid and lithium ion batteries, development of new materials for batteries	Multi-potentiostat / galvanostat,
Characterization of paintings, inspection, monitoring of degradation painting, research and development of new formulations, consulting, cure analysis and standard tests.	Cure laser with CCD camera, thickness, color meter, automatic film applicator, Spectro-guide gloss
Development waste treatment by electrochemical methods	DC power supplier, reactors
Prepare special samples for R&D studies and development of projects in scale before application	Automatic press, System plasma deposition, planetary mixer, high temperature furnace

Figure 13: Activities and main equipment distribution

Conclusions

Brazil is a continental nation, with deep and harmonious diversity, which confers to this country high creativity potential. At the same time, quality science has been developed and improved during the last decades, positioning Brazil as a recognized player in the generation of global quality knowledge. In this context, however, the required instruments needed to convert such science into industrial productivity and sustainability are still being developed, with new Federal and State policies such as "Brasil Maior", "Inova Empresa" or "Embrapii". Data therefore shows that new interfaces are required to accelerate the conversion of science into businesses. It is therefore based on the Fraunhofer Society model, that SENAI, the largest private network of professional education and technological services in the country, has taken over the challenge of interfacing universities and the private sector, with the implementation of a comprehensive network that counts with 26 applied R&D&I facilities, and 59 technology transfer centers.

The early success already achieved by the Electrochemistry Innovation Institute of SENAI in Curitiba, Paraná, shows that this overall strategy shall quickly beneficiate the industry with the development of a new knowledge-intensive products and processes.
The next deeper challenge that SENAI shall now address, is to constitute a real cooperative network of R&D activities all across the country, so that deep complex technological solutions can be developed in order to achieve edge knowledge intensive private sector activities, which will sustain a prosperous human-oriented growth in the challenging and turbulent future years.

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Innovation Through Partnership

Jane Davies

Belfast, Ireland

One of the most difficult concepts to communicate to policy makers anywhere in the world is that innovation, that over-worked word used to describe the mysterious process of creating wealth from creative thinking, is not the inevitable outcome of shiny new buildings, investment in academic research or financial support for business growth. These are all necessary, but not sufficient, conditions to support the development of an innovative city or region. At all levels, innovation is about people, and so innovation capacity can only be built at a human pace, on foundations of existing strengths, combining a range of interventions that remove barriers and support the growth of social capital and trust between the key actors.

This view was echoed in a recent (August 2014) report on the Competitiveness of Cities published by the World Economic Forum[1]. The report presents a four-fold taxonomy of drivers of city competitiveness:

- Institutions – governance and decision-making framework
- Policies and regulation of the business environment – getting the basics right
- Hard connectivity – core physical infrastructure
- Soft connectivity – the city's social capital

1 www.weforum.org The Competitiveness of Cities

It goes on to explain: “Soft connectivity is the social capital that makes investments in hard infrastructure and new technology (e.g. broadband access) more productive, and is now considered as important as hard connectivity.”

In describing my experience in one area of one city in the UK, Manchester, my aim is to identify some of the achievements that have been the result of a partnership approach to improving the soft connectivity of the city, and hence its competitiveness, and the conditions which make this unusual partnership a success.

Context

English cities are at a disadvantage compared with other cities and regions in developed economies because of the UK Government’s lukewarm commitment to devolution despite political rhetoric to the contrary. By keeping a tight hold on the levers of innovation-led economic development, public officials have made it very difficult for cities such as Birmingham, Leeds or Manchester to stimulate their own metropolitan revolution – unlike Bilbao, Munich or Eindhoven. So, city leaders have been forced to be creative about how they maximise economic growth and in 2012, Greater Manchester’s combined authority struck the first City Deal[2] with central government which gave them access to additional funding in the form of a “Revolving Infrastructure Fund” to invest in transportation, housing and skills. An innovative concept enshrined in this 30 year City Deal allows Manchester to “earn back” a portion of the additional national tax revenue from the GVA increase resulting from local investment of £1.2 billion in infrastructure.

A significant input to GM’s negotiations with central government of the City Deal was the Manchester Independent Economic Review (MIER)[3], a report on the current state and future potential of the economy of Greater Manchester, and the first of its kind in Europe. A key conclusion of the MIER was that Manchester is probably the UK city, outside of London, most likely to increase its long term growth rate, to access international markets and enjoy strong connections to the rest of the world. However, it is currently punching below its weight given its size and scale despite having significant economic assets in the form of its universities, international airport, innovation clusters, culture and governance. One such cluster of innovation activity, the Corridor, is located close to the universities, research hospitals and science park, and is focused on the biomedical and healthcare sectors.

2 http://www.agma.gov.uk/gmca/city-deal-announcement/

3 http://neweconomymanchester.com/stories/1769-manchester_independent_economic_review_mier

And it is relevant that In July 2014 there was a further announcement of a Growth Deal[4] between Greater Manchester and central government which secures additional funding to support specific projects. Going beyond infrastructure and public services, the announcement includes a commitment to establish a "life sciences inward investment fund" to support a key priority for local government of "Securing Greater Manchester and the North West of England's place as a major centre for life science in the country."

In the 1980s, Manchester became a classic example of the impact of industrial decline when the consequent job losses affected whole neighbourhoods across the city region in ways that we are still struggling to reverse today. Now the UK's second city in terms of economic activity, it has reinvented itself as the original modern city by exploiting the talent pool associated with its five higher education institutions, several major research hospitals, a culture of inclusivity and a reputation for urban grit and creative flair. Key sectors of its economy in the 21st century include Business, Financial and Professional Services, Health and Social Care, Creative and Digital Media, Education, Advanced Manufacturing and Sport[5].

	Employment	Annual GVA £ billion
Business, Financial & Professional services	278,000	14.2
Health & Social Care	172,000	4.1
Creative & Digital	65,000	3.0
Education	117,000	3.2
Advanced Manufacturing	47,000	2.8
Sport	17,000	0.34

The Corridor, Manchester[6]

One location where Manchester's knowledge assets are physically concentrated is an area south of the city centre, either side of one of the main routes to the airport. Christened The Corridor, it provides employment for 55,000 people – mainly with degree qualification or above – and in term time the population is augmented by more than 72,000 students. Currently, the main institutions on The Corridor are half way through a ten year period of around £3 billion of public and private investment in their facilities. New hospitals, research and teaching facilities have replaced worn out buildings and green spaces have been created as part of a modern campus environment.

4 http://www.agma.gov.uk/cms_media/files/final_greater_manchester_growth_deal.pdf

5 http://neweconomymanchester.com/stories/1776-key_facts

6 http://www.corridormanchester.com

The story of the Corridor can be traced back to 1824 when a group of private individuals, including John Dalton, father of Atomic Theory, established the Manchester Mechanics' Institute, where artisans could be taught by part-time study the basic principles of mechanics and chemistry. Manchester was the world's first industrial city and, even then, availability of skilled labour was recognised as an essential ingredient of continuing growth. After several transformations, the Institute became the University of Manchester Institute of Science and Technology (UMIST) and, in 2005, it merged with the Victoria University of Manchester to become the current University of Manchester[7] (UoM). With close to 40,000 students and 25 Nobel prize winners having studied or worked there in its history, UoM is ranked 38th in the world, seventh in Europe and fifth in the UK in the 2014 Shanghai Jiao Tong World Ranking of universities.

Other key institutions in the area are Manchester Metropolitan University (MMU), a research informed teaching university; the Central Manchester University Hospitals NHS Foundation Trust (Hospital), a publicly funded teaching and research hospital; and several specialised facilities owned and operated by Manchester Science Partnerships (MSP) including the original Manchester Science Park.

The physical clustering of these significant knowledge assets is a happy coincidence, less happy is the fact that the adjacent areas comprise four of the most economically deprived areas in England. High levels of unemployment, crime and antisocial behaviour as well as low educational attainment, aspiration and lack of social cohesion characterise these communities. Also in 2006 the physical environment of the central spine of the Corridor was suffering from very high traffic density leading to safety concerns for pedestrians and high levels of atmospheric and noise pollution; a leisure and retail offer which was largely aimed at students; and poorly designed and badly maintained public realm.

In 2006, the leaders of MMU, UoM and the Hospital formed a not-for-profit partnership with the City Council, the Corridor Investment Partnership. It is constituted as a limited company and its aim is to generate significant growth in economic activity and to create a new destination in the city. Subsequently, representatives of other organisations located on the Corridor (MSP, cultural organisations, Arup, a private partnership of consulting engineers and Bruntwood, a private, Manchester based property investment and management company), joined the Partnership.

The vision for the Corridor is:

Globally and locally, people will recognise the Corridor as a place that is original, creative and smart, where knowledge is put to work.

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7 http://www.manchester.ac.uk/discover/history-heritage/

The remit of its activities are described by five themes, which the partners are comfortable to work on collectively as well as independently within their own institutions. These are Research and Innovation, Sense of Place, Transport, Environment and Infrastructure and Employment, Business and Skills.

Achievements

Initially, the partners were able to cohere around those issues which affected them all but which none could solve alone. These included improving access to employment within their own organisations for local people, developing an infrastructure plan that would deliver the desired changes to public realm and transport and discussing a cohesive development plan for the Corridor which included enhancing the innovation eco-system. Furthermore, as public sector organisations, all four of the original partners were subject to imposed targets for reduction of greenhouse gas emissions as a result of European agreements passed in 2009. The affordability and feasibility of schemes such as green travel plans and heat networks are greatly improved by a partnership approach and so environmental sustainability was added to the Partnership's agenda.

One of the earliest successes was an intervention designed to support local people to access employment in the Universities before they are advertised more widely. The Works[8] won the award for Outstanding Contribution to the Local Community at The Times Higher Education Awards in 2013. It operates out of two facilities based in the adjacent areas and has now attracted other large employers including Barclays and the Post Office as partners. More than a thousand unemployed local residents have now found jobs as a result of targeted efforts to recruit from the neighbouring areas.

Delivered by MSP, Corridor Connections stimulated commercial innovation via cross-sector collaboration through a programme of face-to-face and online interaction. Topics have included 'Retrofit Opportunities', focussing on how to improve the energy rating of existing residential and commercial buildings, and 'Better healthcare through digital technologies', bringing clinicians with problems to gather with digital companies who might have a solution. At a broader level, myKnowledgeExchange[9] is a Corridor project to develop an IT-solution to enable SMEs and other businesses to access the knowledge base residing on the Corridor, including companies as well the universities and hospitals.

A key element of the vision for The Corridor is to retain the knowledge based companies that are created in or attracted to it. If the companies stay and grow, talented people

8 www.theworksmanchester.co.uk

9 www.myke.biz

will work and live in the area and add to the varied human capital that is essential to a thriving knowledge economy. This in turn will stimulate demand for more sophisticated restaurants, bars and retail outlets and the new destination will become reality. A cohesive development plan for the Corridor that would complement the significant developments on the university and hospital campuses required a more considered approach and, in 2008, Zernike UK was retained to assess demand and develop proposals for additional science and innovation facilities within the Corridor.

Their conclusions identified both challenges and opportunities but concluded that the Corridor Partnership "...was the best platform for all the stakeholders to meet and agree a common agenda." The report recommended that MSP should provide "...the management and value added facilities for all new propositions and innovation networks for all the existing facilities in the area.", and that the first manifestation of the common agenda should be the conversion of an existing eye hospital building on the Hospital campus which would become redundant when all activities were transferred to a new facility early in 2009.

Six years later, it's interesting to see that many of the Zernike recommendations were delivered: The Partnership was instrumental in securing UK Government and EU funding to develop the former eye hospital, a protected heritage building on the Hospital campus, into a new 10,000 m^2 biomedical centre of excellence, Citylabs[10], which was launched by George Osborne, UK Chancellor of the Exchequer, in September 2014. It is owned and managed by MSP, carries the MSP brand, and many of the tenants have 'graduated' from the MedTech Centre, a partnership between the Hospital and MSP based on the Science Park.

Evolution of the Partnership

The success of the Partnership as a delivery vehicle depends largely on the commitment of the representatives of the founding partners. As leaders of the biggest organisations in the city, two vice-chancellors, the political leader of Manchester City Council and a main board director of the Trust make a major commitment of their time to the board of the Partnership. Nevertheless, it took some months before the level of trust between board members had developed sufficiently to support objective discussion and compromise of individual agendas for the benefit of the collective vision. Estates strategies, campus development and branding were some of the more sensitive areas.

The Partnership could have disintegrated in its initial stages but several factors combined to prevent this:

10 www.citylabs.co.uk

- the founding partners were party to a legal agreement and had each committed to a contribution of 120,000 euros annually for three years to fund the activities;
- the Corridor board provided access to senior colleagues in a forum which nobody wanted to miss so nobody wanted to be the first to withdraw;
- the seniority of the board members sent a strong signal to their organisations, and the public, that they were committed to the vision for the Corridor so failure would have been publically embarrassing;
- all four partners had identified an issue, public transport, which they could only resolve collectively, and the longer they worked on that together, the more additional opportunities were identified.

Evolution of the Science Park

The Zernike UK recommendations placed considerable reliance on MSP as the deliverer of the soft connectivity that would deliver a result greater than the sum of the parts. A small organisation in comparison with the universities and hospitals, the Science Park was established in 1983 on a brownfield site next to the university campus. Its creation was a response to the high levels of unemployment in the city at the time, and an attempt to create jobs by exploiting the knowledge and talent generated by the university. One factor underpinning its subsequent success was the governance structure: a private company limited by shares which were owned by the city government, the university and the private sector in equal parts. Today this would be described as a triple helix partnership; then it was an innovative ownership structure designed to secure investment and continuing commitment from those organisations that would benefit most from its success. It succeeded.

However, it lacked the resources, particularly the capital, to expand to meet the aspirations of the Corridor partners and in 2012, Bruntwood bought out its existing private sector shareholders and acquired a 51 % shareholding in MSP. The Chief Executive of Bruntwood became its chairman but the universities and cities retained their seats on its board and, subsequently, the Hospital acquired shares and a right to nominate a director. The Science Park thus continues as a triple helix partnership although it was necessary to concede a majority shareholding to the private sector in order to secure the investment needed for expansion.

During the sale negotiations, the academic and public shareholders were committed to retaining MSP's role as the "animateur" of the Corridor's innovation system, as well as securing its physical expansion, Consequently, clauses in the share sale agreement reflect both these objectives and the former function is made explicit in this statement from the Citylabs website:

"The idea of MSP as a hub for an innovation-led business community is important to us, and we pride ourselves on being more than just a location. We reinvest a percentage of the operating profit back into the company in order to provide free business development services for our tenants."

The physical expansion of MSP's facilities has also made progress with the acquisition of two buildings adjacent to its main site, the conversion of one of them and an announcement in August this year of the grant of planning consent for a 6,000 m^2 'innovation centre'[11].

Continuing Collaboration

Ironically, the problem of public transport in the area, the issue that brought the Partners together in the first place, has still not been solved. There have been improvements in public realm; more trees, wider pavements and smarter bus stops and street furniture, but a new express bus system and partial pedestrianisation of the road where it runs through the middle of the university campuses is still awaited. The main reason for the delay is the integration of the solution for the Corridor into a major revamp of Manchester's public transport system including new tram services and rail connections. Funding for the entire plan was only confirmed in June this year.

Nevertheless, creation of new science and innovation facilities continues to strengthen the cluster by expanding the number of companies that can benefit from co-location with the knowledge assets. Even before the launch of Citylabs, "Citylabs2" was under discussion as a second, elderly hospital building on the Hospital campus became redundant. Still in the early stages, this will be a similar configuration of conversion and new build to produce a facility for companies and organisations with objectives that are compatible with those of the NHS.

New partners are also being attracted to the Corridor. The Partnership board is currently chaired by Professor John Brooks, Vice Chancellor of Manchester Metropolitan University (MMU). He has been an active champion of the Partnership's aims whilst also pursuing his own ambition of unifying MMU's operations on two sites on the Corridor instead of the seven he inherited on his appointment. This has involved major investments in new facilities and disposal of the redundant sites in a property market which at best could be described as stable. However, as the UK's economy began to recover from the global financial crisis in 2013, Manchester's commercial property market also showed signs of improvement and the MMU site adjacent to the Hospital was advertised for sale.
This site is one of only two possible areas for new development on the Corridor outside

11 http://www.mspl.co.uk/latest-news/msp-secures-planning-to-kick-start-the-next-generation-of-science-and-technology-innovation-in-manchesters-knowledge-quarter.html

the university and hospital campuses. The other is in the hands of a private developer who is in dispute with the City council over his plans for more retail and student residences. So in this case, instead of leaving the outcome to chance, the Partners, particularly Bruntwood and the Hospital, worked with MMU to find a purchaser that would enhance the developing health technology campus in that area of the Corridor. In July this year it was announced that a €60 million private hospital will be built on the site by Nuffield Health as part of a partnership with MMU. As well as buying the site, Nuffield Health will sponsor a professorial Chair in Wellbeing at MMU and support a range of public health initiatives in the University and the city region.

This press announcement could have concealed a major dispute between MMU, the socialist city council and the National Health hospital – and the fact that it did not is, in my view, largely because the Corridor partnership has developed into a close-knit group that works together to deliver the common agenda of economic growth.

Conclusion

The launch of Citylabs was a good news story for The Corridor and for Manchester that attracted national attention. It also provided the opportunity for MSP to announce a change of name from Manchester Science Parks to Manchester Science Partnerships as a sign of its continuing evolution, and for its Chairman, Chris Oglesby, to make the following statement:

"Citylabs is the embodiment of the partnerships that drive investment and innovation in this city. It is only by working with partners in the NHS and industry that the right environment for investment, growth and discovery in science can be fostered. Today we are celebrating more than just a building. We are celebrating the idea that through partnership, great innovation can be achieved."

The Corridor Partnership took time to mature and hasn't delivered everything it was formed to do, but it has built trust at the highest level between senior representatives of organisations with a vested interest in making their local economy grow. As a result, the "soft connectivity" of Manchester has been strengthened and the Partnership has contributed significantly to the growth of the biomedical and healthcare cluster on The Corridor.

Living Labs: Concepts and Critical Factors, with Case Studies in Health Care

Marina van Geenhuizen

Faculty of Technology, Policy and Management
Delft University of Technology,
PO Box 5015, 2600 GA Delft, The Netherlands.
E-mail: m.s.vangeenhuizen@tudelft.nl

Abstract

Living labs are a relatively new and increasingly popular policy tool to enhance innovation. Many universities, companies and cities today are involved in Living labs to smoothen barriers in collaboration and benefit from the input of user groups with the aim to shorten time to market and a better match of new technology with user needs. Despite their popularity, Living Labs just started being subject of systematic research, for example, on their characteristics, aims and critical factors. First, the paper discusses a narrow conceptualization of Living labs and attempts to position it in-between 'adjacent' concepts. In a next step, the literature is 'scanned' to identify critical factors in the establishment and management of Living labs, and as a final step, this set of critical factors is explored using in-depth studies of four Living labs in the healthcare sector. The main critical factor is an adequate involvement of users and gaining a high level of richness and flexibility in their inputs to innovation. With regard to the 'human factor', patient-oriented Living labs differ from institution-oriented Living labs, in such a way that in the first trust tends to be critical in the relation with user groups, while in the second stakeholder commitment and strong partnership, alongside a multidisciplinary and multi-sector approach, tend to be key.

Key words

Living labs, knowledge commercialization, user groups, critical factors, 'human factor'
Jel code: D83, I1, O31

1. Living Labs: Setting the Scene

Living labs are an increasingly popular policy tool to enhance innovation in different areas, such as sustainable energy, the health sector and information and communication technology (ICT). The concept of Living labs has started to be elaborated since the early 2000s when William Mitchell at Massachusetts Institute of Technology proposed to move research activity from research laboratories to in vivo settings, thereby enabling to monitor users' interaction with innovations in reality. A major contribution to the rise of the Living lab concept came from research on users as an important origin of innovation (von Hippel, 1986, 2005) and new ideas on participatory and convergence culture (Jenkins, 2006; Almiral et al., 2012). Ideas on user-led innovation and the customer-active paradigm have fostered models of co-creation of value by companies, researchers and customers (Pralahad and Ramaswamy, 2004). In this development, the Living lab concept was also significantly 'fuelled' by models of open innovation (Chesbrough, 2003, Chesbrough et al., 2006; Enkel et al., 2009) in which large and small firms and research institutes collaborate in R&D and share the results under certain conditions, with benefits including cost savings, increased user-value and a better (quicker) innovation performance and market access. All this enhanced replacing the 'single-inventor perspective' on innovation by a knowledge flow (inflow and outflow) model between partners in the process with an emphasis on involving user-groups early and more actively. Most experience with developing and managing Living labs in Europe has been gained by the ENoll network fostering the introduction of ICT-based innovations in European societies (EC, 2009; ENoll, 2014).

In addition, more recently, the model of innovation in our society started changing to include a more prominent position of the public sector and civic society, connected with various large societal challenges that are waiting for solutions, like in transport, energy use, health among elderly, safety, etc. as forwarded by the European Commission in the document Horizon 2020 (2010). Accordingly, the aim of innovation and of parts of university research is shifting towards finding solutions that are wanted by societal actors, for example, those being confronted with challenges in cities (Goddard and Vallance, 2013).

Broadly speaking, there are two conceptualizations of Living labs in the literature (Følstad, 2008; Guldemond and van Geenhuizen, 2012). First, Living labs are seen as open innovation networks or platforms with strong user involvement, emphasizing on the role of intermediary that coordinates network partners in open innovation (Katzy, 2012), and secondly, more narrowly, Living labs are seen as delimited real-life environments (physical places) including a network of actors, specifically with strong involvement of user-groups, emphasizing on increasing user-value. The two conceptualizations do not exclude each other, the second one could be part of the first one. The perspective that is adopted in this paper is the Living lab in a narrow sense.

Living labs in a narrow sense share various characteristics connected to three dimensions: a) an early and active involvement of user-groups in co-creation; b) a real-life environment representing the living/working environment, for a short or longer time; and c) a relatively open network providing structure and governance of actors sharing the desire to quickly take-up innovations in the market/society. However, even using a narrow vision on Living labs, these may be different in structure and processes, dependent on which actor drives the operation (Leminen et al., 2012; Nystrøm et al., 2014). This difference would, for example, distinguish between user-driven Living labs, with inhabitants or patients or their advocates as drivers while focusing on better solutions to problems, and company-driven Living labs focusing on achieving higher user-value and bringing inventions quicker to market. The last situation would also matter for institution-driven Living labs, like hospitals and universities.

As a result of their popularity as an innovation tool, Living labs are now increasingly subject to systematic research (e.g., Almirall et al., 2012; Leminen and Westerlund, 2012, Leminen, 2013; Ståhlbrost, 2012; Dubé et al., 2013; Sauer, 2013). However, there is still weak attention to critical factors in the establishment and management of Living labs, and as a result it is not clear under which conditions Living labs can speed up in designing the best solutions to societal problems or to user-value of consumers and shorten time-to-market. This knowledge gap can be ascribed to the lack of a uniform definition and often fuzzy 'stretching' of the concept into different directions, including related concepts and approaches (Leminen, 2013; Nystrøm et al., 2014). Against this background, the research questions of this paper are the following:

1. What is the relation of Living labs as a narrow concept with 'adjacent' concepts or approaches?
2. What are the critical factors in set up and operation of Living labs?
3. How do these factors manifest themselves in medical Living labs as specific types of Living labs?

The study draws on a scan of the literature and workshop experience (note 1) enabling the identification of critical factors, and is structured as follows. In section 2, the concept of Living labs is clarified and illustrated using three dimensions, namely, user involvement, real-life environment and networks of relevant actors, and 'adjacent' concepts are identified on the basis of these dimensions. The three dimensions are also leading in identifying critical factors in the literature in section 3. Section 4 encompasses four in-depth case studies in healthcare, aimed at a further exploration of the critical factors. Section 5 provides conclusions and suggestions for future research.

2. Living Labs and ‘Adjacent’ Concepts

2.1 User involvement

As above indicated, in this paper Living Labs are conceived in a narrow way. Accordingly, Living labs are delimited real-life environments, in which user-groups are actively involved as co-creators/designers in a network encompassing researchers and other relevant actors, enhancing business innovation and/or social innovation. The practice of Living labs includes various key activities related to co-creation (Pralahad and Ramaswamy, 2004) in living settings and living communities:

- Joint problem definition and problem solving and joint creation of solutions, using experimentation in implementing and testing the created solutions.
- Creation of an experience environment in which user-groups have dialogue and co-construct personalized experience together researchers and producers.
- A broad evaluation of experiences, new concepts, and user value according to e.g. ergonomic, medical, social cognitive and socio-economic criteria, and actual market opportunities.
- Exploration of emerging uses, future market opportunities, etc. using e.g. scenario thinking.

Users are not a homogeneous group. There are various types of users and they require different approaches in the management of Living labs (Arnkill et al., 2010; Almirall et al., 2012). According to their place in the market, a distinction can be made between lead users and ordinary users. Lead users are defined as those on the leading edge of an important market while they are typically facing needs that will later be experienced by large groups of ordinary users in the same market (von Hippel, 1986, 2005). So, in the case of certain products and services of which the marketing requires lead users acting, this type of users is important to be included. Ordinary users, by contrast, are part of established markets, where existing solutions are improved and products/services are customized to user needs and preferences, as part of a growing trend for ‘personalization’ of goods and services (Mohr et al., 2010; BDC, 2013).

Aside from consumers, many companies and not-for-profit organizations act as users of innovations, namely, in an intermediary step towards an end-product. And increasingly, pressure groups (civic society bodies) are getting powerful in signaling societal problems and challenges while being prepared to engage in co-creation of solutions, e.g. in housing, traffic, urban greening, health care (Trenscher et al., 2013).

With regard to the degree of user-involvement, a whole range can be observed, running from users as leading co-creators at one extreme to users as passive subjects at the other extreme (Arnkil et al., 2010; Almirall et al., 2012). In the narrow conceptualization of Living labs in this paper, only those types of involvement are included which are ‘located’ at the extreme of co-creation or close to that. However, a combination of co-creation with less strong involvement modes also happens in the practice of Living labs (Nystrøm, 2014). In those cases where user-involvement is basically passive, 'adjacent' concepts apply like test beds and field labs, in which users act more passively in forwarding experiences and preferences and are not involved in co-creation (Almirall et al., 2012) (Table 1). Also, the so-called communities of practice (CoPs) may be mentioned which comprise of social groups of people with a shared interest that collaborate in social learning networks (Wenger, 1999). The aim is learning from each other in finding solutions, not necessarily learning interactively with producers and researchers.

2.2 Real-life environment

The real-life environment in Living labs is different dependent upon the domains in which innovations and solutions are being created, which may cover applications in healthcare and cure (HICD, 2012; Kehayia et al., 2014), sustainable housing and safety, campus life (universities) and shopping behavior, etc. (König, 2013). Accordingly, Living labs may include hospitals, living houses, a living quarter, a public transport station, a university campus and a shopping mall, etc.

If the spatial scale is extended to segments of cities and entire cities, we come close to the concept of Smart Cities (Table 1), which are those cities in which digital technologies translate into better public services for citizens, better use of resources and less negative impacts on the environment. Furthermore, it encompasses a more interactive and responsive city administration, safer public places, more efficient ways to light and heat buildings, meeting the needs of an ageing population, etc. (Batty et al., 2012; EC, 2012), thanks to a technical infrastructure, including real-time feedback sensors, wireless networks, and software to manage the data. In this vein, the idea has developed that Smart Cities can be used not only for monitoring and steering but also as real-life ground for interactive experimentation and creation of new ideas and technologies solving persistent urban problems, and this is where Living labs 'enter'.

A related and rather new concept is that of Urban Transition Lab, which has the particular goal to bring about transitions towards higher levels of sustainability in an urban context and across multiple domains (Nevens et al., 2013). Transitions in this line of thinking are to be seen as societal processes concerning systematic innovations, not only entailing new technological solutions but also – and as preconditions – changes in markets, institutions, infrastructures, cultural discourse, policies and governing institutions (e.g. Geels and Schot, 2007). Typical for the Urban Transition Lab is the focus on specific characteristics of the city and on intertwining of multiple transitions, e.g. energy, mobility, built environment, food, ecosystems, etc. (Nevens et al., 2013). Accordingly, research and innovation are integrated through systematic co-creation, exploration, experimentation and evaluation of innovative ideas, scenarios on transition in real-life use cases, particularly identifying lock-in situations that may block transitions. In some approaches, universities are given a key role in such sustainability increasing processes in cities (König, 2013). Being relatively broad, the Urban Transition Lab approach may make use of Living labs, aside from various other tools and practices.

Connected to the Urban Transition Lab approach is the local niche as a protected environment allowing for learning and experimentation in the context of transitions, but in which there is no explicit role for users as co-creators (Schot and Geels, 2008; Smith and Raven, 2012). Also, protective niches deal with path-breaking innovations that are facing fierce competition in the market and stiff barriers from institutions, calling for protection of the application from market forces, which is not necessarily true for solutions and innovations practiced in Living labs. However, niches may act as Living labs if the learning is coupled with co-creation.

2.3 Networks of relevant actors

In this section, attention focuses first on actors that are directly involved in the set-up of and activities in Living labs (core network) while 'adjacent' concepts are discussed next.

The motives and interests of the core actors in Living labs are partially similar and partially different, as the following main lines indicate (Almirall et al., 2012; Leminen, 2013):

- *User-groups:* as end-users they are facing a specific problematic situation or the challenge of getting the quality of products/services better matched with needs, taste/preferences, etc.; or as companies, they feel the need for a better quality of goods/services as inputs to their business processes.
- *Universities and research institutes:* they provide part of the knowledge, eventually in co-creation, with the intention to bring it to market (as their 'third' mission) (van Geenhuizen, 2013). Living labs tend to produce more valid testing results and provide better learning about customer wishes compared to research labs. In addition, today, universities develop a stronger interest in solving societal problems and acting in a responsible manner towards society, also evident in initiatives to 'transform' part of campuses in a Living lab (Goddard and Valance, 2013; König, 2013).
- *Companies, large and small ones:* they intend to provide better quality and new products/services for which they need user feed-back and co-creation in matching with user needs, all serving shortening of time-to-market and decreasing risk of failure (Prahalad and Ramaswamy, 2004; Nystrøm et al., 2014). As indicated above companies can also act as users.
- *Financial institutions:* they invest in individual projects/programs or in Living labs at large which appear to be promising in gaining good results in new products/services and to be worth the effort of investment. Examples are difficult to find so-far, as quite a lot of Living labs are financed by large companies and/or public subsidies.
- *Municipalities and other public authorities:* if involved, they may have various roles/interests, e.g. acting as a facilitator, a neutral actor, or a leading actor if problem owner and user, like in primary education, elderly care and public services (e-governance).

The above mentioned list indicates that interests and stakes may sometimes be considerably different between actors in the network, like in terms of the preferred direction of solving a problem and in terms of amount of power, like between multinationals and local authorities. Also, roles and power may quickly change, contributing to complexity in management (Nystrøm et al., 2014).

With regard to 'adjacent' concepts (Table 1), the open innovation networks/platforms with roles as nodes and intermediaries in larger innovation networks and in multi-organizational collaboration can be mentioned (Almirall and Wareham, 2011; Katzy et al., 2012), Living labs in a narrow sense eventually being part of them. The broader concept could also include an 'ecosystem' approach with attention for new entrepreneurship where Living labs or any other learning network are connected to incubators of high-tech ventures that bring the (improved) innovation to market. There are various examples in practice, like in the ENoLL network (ENoLL, 2014).

A more focused approach in the sense of specific actors in the network is that of the Triple Helix, including universities, policy institutes and businesses, aimed to benefit from each other's capabilities and activity in pursuing the common aim of improving innovation performance, forwarded already since the mid-1990s (Etzkowitz and Leydesdorff, 1997; Etzkowitz, 2008). Today, user groups are also involved as a main actor (Quadruple Helix) and Living labs may act as one of the component in such networks (Füzi, 2013; van Geenhuizen, 2013; König, 2013; Ranga and Etzkowitz, 2013). More specifically, much literature has been devoted to barriers faced in a more integrated approach of universities, companies and public authorities but also to a trend of convergence (D'Este and Patel, 2007; Bjerregaard, 2010; Bruneel et al., 2010). In this vein, Living labs could act both as boundary organizations operating at the interfaces between science, market and policy (Meyer and Kearns, 2013) and as a (temporary) node in themselves.

To conclude, Living labs in a narrow sense can be 'extended' along various dimensions and in most of the initiatives, Living labs may act as a specific part of the learning and innovation networks. One 'extension' that has not been addressed so far, is the virtual environment. Living labs can work well with virtualization of changes in the environment or user objects, as an instrument in enhancing imagination and creativity.

Table 1. Living labs (LL) in a narrow sense and 'adjacent' concepts a)

Dimension	Characteristic of narrow LL	Differences with LL	Concept/approach
User-involvement	Active involvement (co-creation)	-Weaker involvement in creating solutions/innovations -Absence of different actors	-Field-laboratory or testing field -Community of Practice
Real-life (physical) environment	Limited and physical	-Larger scale and focus on monitoring of urban conditions and user behaviour (may include LL if using data for co-creation)	'Smart Cities'
		-Emphasis on radical innovation, urban transition, and multiple domains (may include LL) -Emphasis on radical innovation and learning under protection against market forces (may act as LL if learning is coupled with co-creation by users, producers, etc.)	-'Urban Transition Lab' -Local niche
Network of actors	Relevant actors performance/ management	Larger networks and more functions (may include LL)	Innovation platform/ network and role of intermediary
		Selected actors: universities, public bodies, businesses, user groups (LL may be part of the networks involved)	Triple/Quadruple Helix

a) Not exhaustive

3. Preliminary Set of Critical Factors

Most Living labs act as public-private-people (civic) partnerships with dual sources, but they are often still substantially financed on the basis of subsidies and grants. So far, investment in Living labs seems not a critical factor in the set-up and operation of Living labs. Six factors related to other features than investment are found in the literature, as discussed below.

First, the involvement of user-groups is most often mentioned as a critical factor, particularly the need for an adequate selection and the need for a close and intensive interaction with researchers and producers. As previously indicated, this requires a sufficient match between R&D issues and user needs, capabilities and experience. It is therefore of great importance to select the *right* user groups and to provide them with adequate motivation. The right user means that he/she is sufficiently committed to finding a solution and able to contribute actively by a sufficient skill level, like in dealing with information tools and in communicating personal needs, experiences and future expectations (scenarios). The idea of adequate motivation touches, however, upon some ambiguity which seems difficult to solve. On the one hand, it is important to include sufficiently motivated users, like lead-users, but on the other, including the not-motivated persons seems also important in order to reveal the reasons behind a lack of motivation, in particular if these persons belong to the potential market segments of the near future.

Secondly and by definition, the real-life environment is crucial. However, nowhere in the existing literature, the real-life environment is addressed as a factor that deserves some key attention in the selection and management. This is remarkable because the physical dimension introduces questions on, for example, access and openness of the room or building(s) in relation to what is public and what is private, and on legal aspects of implementing infrastructures in those places, to mention an example. Complexity may increase if the spatial scale of the initiative is stretched towards city quarters and whole cities in the Smart City approach in which co-creation has a place, producing challenges of coordination and management.

As a third factor, the composition of actors in the core network tends to be as important as the involvement of users. It is worth mentioning that a too large number of actors and dominance of one of them as well as a strong dependency between actors need to be avoided. If many different actors are involved, particularly with contrasting opinions and interests, there is a large chance for conflict and delay in decision-making, whereas a strong dominance of one large actor may deter smaller parties to participate (Guldemond and van Geenhuizen, 2012). Openness and neutrality is important, particularly to avoid one actor playing a dominant role. In addition, if there is strong dependency between two or three actors, withdrawal by one in times of conflict may cause withdrawal of others, making survival of the Living lab or its constituent programs very difficult, as insights from complex projects illustrate (Flyvbjerg et al., 2005; Verburg et al., 2005; de Bruijn et al., 2010). Needless to say, that the quality of the management of the core network is crucial, being able to avoid imbalances between actors in this network and to manage expectations.

Related to the composition of the actors is the management attention needed for dynamics in the roles actors may adopt in reaching the aim of the Living lab, such as coordinator, messenger, facilitator, integrator, etc. A recent study has revealed that sufficient attention needs to be given to patterns like ambidexterity, multiplicity, and temporality (Nystrøm et al., 2014). Role ambidexterity means that users may act simultaneously as 'role-takers' in providing advice and new ideas, and as 'role-makers' as active co-creators in making their role. Roles are in principle temporary as they change with adaptations in the network and can be replaced by other roles. As a result of open innovation, role behaviour in Living lab's networks tends to be more unpredictable and dynamic than in established and conventional networks, calling for stronger attention in their management (Nystrøm et al., 2014).

A fourth crucial factor is the way in which the innovation process is structured. Living labs constitute the environment in which practical innovation proposals and projects are being developed, scanned and eventually forwarded for gaining investment. These activities require a clear model, like a funnel, as well as a transparent decision structure including go/no-go decisions in order to achieve sufficiently attractive business propositions (Guldemond and van Geenhuizen, 2012). As a fifth factor we mention the use of ICT. There is a need to involve sufficient ICT to enable monitoring and analysis of user responses to inventions and product improvements, and in the design/creation activities by users if, for example, simulation is involved. At the same time, it seems important to avoid ICT to be the driver of projects, particularly where the mental distance between the technology and user-groups is relatively large, due to culture and/or age.

And finally, there is a set of values and practical requirements that so-far have arisen in the practice of Living labs and need to be sufficiently settled prior to the start of the initiative (Dutilleul et al., 2010). These include ethical and legal issues concerning privacy, liability and intellectual ownership, but also particular values, like aspects of trust creation in relationships with users.

4. Case Studies of Living Labs

4.1 Introduction

Despite the many inventions in medical technology and care, still a lot of R&D needs to performed to bring healthcare inventions to market and to have them customized to user needs (e.g. Nambisan and Nambisan, 2009; Shah et al., 2009), efforts in which Living labs seem to be considerably helpful and have a large potential. There are two reasons why attention to the healthcare sector in this paper is justified, first, the need in our society to keep the healthcare system affordable, given the increased share of elderly in the population and increased incidence of chronic diseases, while at the same there is the need to improve healthcare services in terms of effectiveness. Secondly, the medical sector is faced with strong actor-complexity, including different types of users and other stakeholders, like patients, surgeons, care professionals and hospitals, as well as insurance companies (reimbursement), regulatory agents, universities, large and small pharmaceutical and medical technology firms, public authorities, NGOs, etc., placing high demands on composition of the networks and its management.

This section presents four case studies to further explore and assess the importance of the previously indicated six factors. In order to reveal sufficient differentiation, the selection is as follows: a simple and a more complex one, both in ambient assisted living for elderly, a relatively simple one concerning a hospital and medical technology (e-health) also involved in some virtual aspects, and a complex one in a shopping mall aimed at improved mobility of disabled persons. Case study 1 represents small projects on ambient assisted living technology for elderly, with the objective to extent the time of living independently at home by use of smart homes (home automation) and e-health tools, including those for home fitness. Case study 2 deals with the same type of applications, but the Living lab is more comprehensive and has also addressed different roles of the users. Case study 3 represents various focused projects, exploring simulation potentials in hospital design/construction and in health product/service development in e-health (telemedicine). And finally, case study 4 is a comprehensive project located in a shopping mall with the aim to increase physical and social inclusion of disabled people, thereby making use of more comprehensive actor roles, both for the disabled and rehabilitation service providers. The main data source for our analysis is the ex-post evaluation of each of the case studies (projects), except for case study 4 which is in a preliminary evaluation stage (Kop, 2011; Ruff and Jakobson, 2012; Amsterdam Region Care & ICT, 2013; Kehayia et al., 2014).

4.2 Living labs for ambient assisted living (Case study 1 and 2)

Case study 1, Doornakkers in the Eindhoven Area in the Netherlands targeted a rather specific user group, namely, elderly from Turkish origin. In terms of technology, the Living lab was relatively simple without brand-new innovations. The Living lab started in 2010 with the aim to provide accessible ICT tools for home care and home fitness training and to have the technology adapted to the specific user group. The major driver was a societal one and the major complexity was social, given the cultural barriers with the user group (Kop, 2011). The Living lab had no (direct) relation with university research and therefore played no role in bridging gaps between these organizations, also the financial risks were relatively low. The network was also relatively simple, without dominance of partners.

The way of involvement of the user group in this type of Living lab turned out to be of key importance, particularly given the cultural background of the users and 'distance' between modern ICT and their living world. Results have been gained by a careful approach, including a solid preparation of the project by learning about user-needs already prior to the project design, and by employing a trainer/coach from the own (Turkish) community thereby enabling the creation of trust between users and researchers. These two critical factors are additional to the ones already addressed in the literature (Table 4, under point 1 and point 6). Furthermore, different from the lines in the literature, a particular structuring of the innovation process was not necessary because no large numbers of inventions were expected to emerge, but the process was kind of open allowing the users to be more active and show up with innovative applications not foreseen prior to the start. Commercial aspects received minor attention in this Living lab. In terms of final outcomes, the target group indeed turned out to become more involved in home-fitness and improved physical condition, they accepted some ICT-based health and safety support, and showed up by themselves with particular safety protection in their house (bathrooms).

Table 2. Local Living labs: elderly housing and ambient assisted living

	Case study 1	Case study 2
Name	Doornakkers: living area Eindhoven (Netherlands)	Living Lab Amsterdam
Working years	2010–2011	2011–2013
Application domain	ICT (domotics) and health care, later on also home safety	ICT (domotics) and health care
Aim and means	Affordable healthcare and illness prevention, by increasing use of ICT tools for home care and fitness training	Affordable healthcare and illness prevention, by increasing acceptance of ICT tools for housing and home care.
User group and roles	Elderly of Turkish origin; passive role but could switch to active	Elderly (different groups); combination of roles (passive and active)
Physical setting	Living quarter: homes	Various independent 'senior houses'
Core network actors (other than users)	Care provider; Eindhoven city and Province; Brainport Innovation	Amsterdam Region Care & ICT; Amsta care society; Amsterdam city and Province; University of Applied Science, University of Amsterdam, Free University; Waag Society (creativity input)
Attention for actors' role	Role ambidexterity among users possible	Sufficient attention for role ambidexterity among users, and dynamics in roles of other actors
Structured innovation process	Open structure, allowing new applications entering the project	Open structure, allowing new applications entering the project
Role of ICT	Culture gap between 'soft' care and ICT, but well managed. Ease of use required	Culture gap between 'soft' care and ICT, but well managed (ease of use). Sensor systems need to be safe (privacy) and inspiring trust
Practical values/ requirements	Respecting cultural values	Privacy protection Maintaining desire for self-determination
Additional critical factor(s)	1)Preparation of project: study of user needs *prior* to project design 2)Employment of specific coach/trainer to develop *trust*.	1)Mixed methods of user involvement 2)Multi-disciplinary approach. 3)*Trust* needs to be gained before project start.

Source: Kop (2011); Amsterdam Region Care & ICT (2013). Partially adapted from van Geenhuizen (2014).

Case study 2 (Living Lab Amsterdam) is a more extended and more lasting version of the first case study – basically with the same aim – but it is also clearly embedded in university research. The approach to user involvement can be characterized as a mixed method of more and less active involvement, including giving interviews on testing the ICT applications, designing scenario's on future use, acting in a focus group and co-creation of specific applications, all with the aim to get a rich and comprehensive feedback and input from the users. The Living lab started in 2011 at various locations of independently living elderly in the Amsterdam area. The sensor technology used in this project served two goals, namely, to measure activities of daily life (ADL) indicating the level of independence in living and need for support, and to make combinations with other products and services, such as an alarming system, a mood button, etc. Trust between the elderly and researchers and care professionals was increased in two ways, namely, by using already established personal relationships with the elderly and by showing a clear proof of working of the new solution already before project start.

With regard to the sensor system and monitoring technology, privacy turned out to be a serious issue aside from the desire of being able to switch-off the system. The last appeared important in relation to the wish of self-determination. In addition, the time of installation of the sensors in the homes turned out to be an issue, i.e. prior to the invitation to participate or after that invitation, which was essential in making a choice by the elderly for participation. Overall, commercial aspects of the applications and other business issues were somewhat neglected in this Living lab. The additional critical factors that appeared can be summarized as: mixed method in user-involvement, a multidisciplinary approach and an early building of trust. Also new was the value attached to self-determination by the elderly, avoiding a too strong dependency on the technology. The main results of this Living lab can be summarized as an increased acceptance of ICT tools for living and home care, and additionally a much better insight into wishes and values of elderly in these respects.

4.3 Institution-related Living labs

Case study 3, Health Innovation Lab (HIL), is part of a larger initiative in the Copenhagen region, Denmark, named Healthcare Innovation Centre. Started in 2009, it was small in scale and had a unique aim, namely to design a *methodology* in healthcare innovation (hospital design and e-health solutions) that combines user-driven innovation and simulation. In 2010 to 2012, it was in the stage of demonstration projects (simulation labs) and various projects were accomplished in 2012, for example, Outpatient Clinic of the Future and Mobile Blood Test Results. The goal of each demonstration project concerning the university hospital was to identify and realize solutions that are scalable and transferable to similar departments in other hospitals. Different from the previous case studies, hospitals were also involved as a user group, derived from their demand for inventions in new construction of hospital buildings and room design, like operation theatres and patients' waiting rooms. Accordingly, users from relevant background were involved in the core network and, in this context, a critical factor turned out to be the matching of users' capabilities with requirements to handle simulation tools.

Regarding the innovation process, HIL used the funnel model, but go/no-go decisions were less relevant in terms of commercialization, because the main output of HIL was a viable innovation tool for (own) use in one of the hospitals in the region. ICT did play an advanced role in the simulation tools and in the application in e-health, including remote treatment and monitoring, but also data retrieving from readings at home and remote dialogue. With regard to practical requirements in HIL's performance, ethical and legal issues seemed less relevant, but a tight management model was forwarded as particularly important, allowing for openness in the first steps and closing the innovation process later on. Unlike the two previous case studies, HIL organized training and team-building to stimulate all parties to interact proactively and to accelerate processes. HIL so-far does not demonstrate early investment of commercial parties from the start, as it is for a large part publicly financed (national and regional authority).

HIL has been subject to a comprehensive evaluation, related to its character as a set of demonstration projects (Ruff and Jacobsen, 2012). Some of the best practice factors derived from the evaluation can be summarized as follows: multidisciplinary input, willingness to take risk and a passionate decision-making by managers, and open dialogue and communication. Accordingly, much value is attached to the 'human factor' among network partners. Main gains of the project are sets of rules to which particular innovations (hospital, e-health) need to respond.

Case study 4 arose from the converging goals of scientists in rehabilitation and rehabilitation services providers to enable persons with a disability to resume their previous level of function and life roles after discharge from rehabilitation (Kehaya et al., 2014). The Living lab is part of a comprehensive approach to improve inclusion of the disabled both physically and socially, and is situated in a shopping mall in Montreal, with the aim to find better solutions, concerning e.g. wheel-chairs' navigating and way-finding technology, as well as interventions in reconstruction of the shopping mall. The Living lab is organized in such a way that the user-groups, disabled persons and rehabilitation services providers, are in a situation to adopt different roles like co-creating, testing, being part of focus groups, etc. The project started in 2011 and is now in a preliminary stage of evaluation.

Industry partners have a stronger role in this case study compared to the other three ones, because they have the responsibility to co-create the solutions and bring them to the pilot stage. Regarding the structure of the innovation process, using a certain selection model for viable solutions, turns out not to be an issue. However, with regard to practical requirements/values, a strong commitment of the core actors is forwarded as important. Potentially, progress of the project is enhanced by a broad setting of activities in the spirit of participatory action research, community of practice (CoP) and international research and business relations, not observed in the other case studies. A formal evaluation is currently under way, causing the critical factors identified so far only to cover the strong partnerships within the core network as the most salient, aside from the multidisciplinary and a multi-sector approach. The last encompasses, for example, shopping, transport, and psychology.

Results of the Living lab can be summarized as improvement in wheel-chair and navigation technology and refurbishing needs of shopping malls, and additionally much insight into the multidisciplinary and multi-sector aspects due to an extensive involvement of various university faculties and other learning partners.

Table 3. Living Labs: Hospital settings and shopping mall

	Case study 3	Case study 4
Name	Healthcare Innovation Lab, (part of Health Care Innovation Centre), Copenhagen, DK	Rehabilitation Living Lab (Montreal downtown shopping mall Alexis Nihon), Montreal Canada
Working years	Feb. 2010–2012 (demonstration projects)	2011–...
Application domain	New medical services and organizational concepts in hospitals	New technical solutions (rehabilitation) to remove social and physical barriers in shopping malls
Aim and means	Design of methodologies of user-driven innovation in identification of innovation potentials in hospitals and telemedicine (using simulation*)	Develop technology and intervention (e.g. rehabilitation and reconstruction in shopping malls) to increase inclusion of persons with disabilities
User groups and roles	Clinicians and hospital (University Hospital Herlev), also patients: highly active and interactive (simulation)	Disabled persons and rehabilitation service providers: active role and changing types
Physical setting	Hospital (diverse rooms) and homes (telemedicine)	A 'renovation' ready shopping mall
Core network actors (other than users)	Regional hospitals; Capital Region of Denmark and Danish Business Authority (both financial investors)**	Shopping mall organization and merchants, various universities (including abroad), community based associations, companies

Attention for actors' roles	Flexibility required	Not an issue so far
Structured innovation process	Open process followed by closing in next steps (funnel)	Not an issue so far
Role of ICT	Part of the main methodology (simulation) being created	Part of the solutions (e.g. smart wheelchairs and adapted GPS system)
Practical values/ requirements	To smoothen input from users: an adequate selection on capabilities	Deep commitment of actors to success of the project
Additional critical factors	*Operational/process management* -Tight management of openness and closing of the innovation process -Management back-up across sectors -Need for trust creation between actors -Multidisciplinary input *Best Practice examples:* willingness to take risk; passionate decision-makers; open dialogue and communication, etc.	*Organization* -Interdisciplinary and inter-sector nature -Excellence in rehabilitation research -Strong partnerships with stakeholders -Linked with a community of practice -Initiatives underway to monitor progress, evaluate outcomes and identify research gaps

*Simulation of real-life and imaginary situations to generate new ideas and inventions.
** Regional Innovation program, partly financed by Ministry of Economic Affairs.
Sources: www.centerforsundhedsinnovation.dk; Ruff and Jacobsen (2012). Kehayia et al. (2014). Partly adapted from van Geenhuizen (2014).

4.4 Summary of critical factors

The factors as identified in the literature and further explored in the case studies are displayed in Table 4. Two factors from the literature appear less important in the sense of a key issue, namely avoiding imbalances in power in the core network and a structured innovation process, this is caused by a limited involvement of the business sector (except for case study 4). Furthermore, we observe important details concerning the main factors. The first case studies on elderly indicate importance of a timely preparation to learn about user-needs and specific values and how to deal with these needs in creation of additional trust, a situation that may hold true for all categories of 'vulnerable' users in healthcare. By contrast, the organization-orientation of the hospital and shopping mall case studies indicates importance of strong links and commitment between stakeholders and a thorough multidisciplinary and multi-sector approach to the innovation process.

Critical conditions concerning actor-involvement (core network) include a solid management of roles in terms of flexibility and differentiation and paying attention to specific values of users, like derived from the own culture, need for privacy and need for maintaining a certain amount of self-determination. The third case-study is a somewhat exceptional class of Living labs encompassing different types of users to provide input in the design of hospital rooms and e-health tools mainly derived from simulation, which seems to require another type of management, however, still with trust as an important component.

Table 4 Critical factors in Living labs' set-up and operation

Factors	Details
1. Involvement of users	-An adequate user-group selection and involvement: - sufficient motivation among users - sufficient capabilities among users to perform their roles -A timely preparation to dealing with 'vulnerable' users (prior to projects)
2.Real-life environment	-No critical factors found, but important legal issues concerning access to places and dealing with infrastructures (ICT)
3. Actors' network (core) and management	-Involvement of all relevant actors, but avoiding a too large number of actors, a clear dominant one and strong interdependency between 'powerful' actors -Sufficient openness and neutrality -Sufficient management attention to the different roles of core actors, e.g. regarding role multiplicity and flexibility -If organizations involved, a thorough multi-sector and multidisciplinary approach -'Human' factor in management: trust-building, passion, strong commitment
4.Structured innovation process	-A 'funnel' or other selection mechanism of promising projects with transparent go/no-go decisions
5.Role of ICT	- Strong involvement of ICT for monitoring and analysis of user responses to inventions, and for performing part of the co-creation/design role -Avoiding ICT to act as a main driver, unless its adoption is subject of analysis
6.Practical values and requirements	-Sufficient attention for ethical/legal issues, like legal liability and IP issues -Sufficient attention to values of user groups, like privacy protection, cultural identity and wishes of self-determination

Source: Partly adapted from van Geenhuizen (2014)

Conclusion and Recommendation

Living labs have emerged as an innovation tool since the early 2000s, under the interplay of several important changes in knowledge creation and innovation. Despite the many initiatives of Living labs, mainly in the ICT domain, systematic studies on how they work and what is critical in their set-up and performance have emerged only since the 2010s, most probably due to the lack of a uniform definition and fuzzy use of the concept. This situation is the reason why this paper adopted a narrow definition and identified various 'extensions' of it. Next, in a search for critical factors for Living labs to gain their aim, six of such factors were derived from the literature of which the most important tend to be: involvement of users in co-creation and interactive learning and involvement of all relevant actors while avoiding a too large number of them and imbalances in power, and with sufficient attention for flexibility and changes in roles of actors involved;

In evaluating the case study analysis concerning healthcare, first, two factors appeared not or less important, mainly due to the limited involvement of the business sector, namely, avoiding imbalances in the composition of actors and working with a structured innovation process. Secondly, the list needed to be extended with important details on the 'human factor' in management, and it appeared that management requirements are different between person-oriented Living labs compared to organization-oriented Living labs.

As always, the current research suffers from some shortcomings, one is the limited area in Europe from which three of the four case studies were drawn, namely northwest Europe, which may cause limitations in generalizability of the results, due to specific cultural traits (Hofstede and Hofstede, 2005). A second is the limited exploration so far of the list of critical factors, namely, by only four case studies and confined to the healthcare sector. Next steps in the research, therefore, could include data collection to establish a larger sample, in order to perform a quantitative analysis. With regard to this, it needs to be decided which countries to include, across and outside the European Union, which sectors to include, namely to enable to test the list outside the healthcare sector like in sustainable energy and safety, and which types of Living labs to include, like person-oriented and organization-oriented ones. And finally, there is a need for a more or less 'standard' framework for ex-post evaluation of Living labs. The evaluation studies used in this paper differed in terms of detail and emphasis on processes and organizational issues. Future studies, therefore, may also develop and design a 'standard' framework for the evaluation of Living labs, given the aims that are set. Such a framework could include the final outcomes of a Living lab, in terms of how long the development of an innovation has taken and which additional new innovations have emerged, and presence of the processes that are needed to reach such outcomes, and it could encompass a generic (core) as well as specific additional modules dependent on the sector and type (orientation) of the Living lab.

Note 1

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Knowledge Transfer and Technology Commercialization – Comparative Study[1]

Małgorzata Grzegorczyk

University of Lodz, 22/26 Matejki Street, Lodz, 90–237, Poland.
e-mail: mgrzegorczyk@uni.lodz.pl

Dariusz Trzmielak

University of Lodz, 22/26 Matejki Street, Lodz, 90–237, Poland.
e-mail: dtrzmielak@uni.lodz.pl

Abstract:

The paper presents results of the research conducted in a form of in-depth interviews and an online survey mirroring a series of target groups: scientists and entrepreneurs in Poland, two developing EU countries (the Czech Republic and Hungary), two developed EU countries (Norway, France), USA and Canada. The aim was to gather insights concerning a model of cooperation between science and business in the process of knowledge transfer in Poland. The work involved a comparative analysis with systems identified in: developed European countries; European countries similar to the Polish stage of development of knowledge transfer; the USA and Canada. The results shows that Polish respondents underestimate the relational factors like: active entrepreneurs in initiating cooperation, responsiveness, openness, trust, and good communication skills. Good relationships between scientists and businesses should be built based on two main characteristics: activity of entrepreneurs and scientists openness for business needs. Both academics and entrepreneurs rank the existence of mutual understanding of each others' needs and commitment as essential.

Keywords

university, knowledge transfer, commercialization, innovation, entrepreneurship, Poland.

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Introduction

The subject of the publication is the knowledge and technology transfer system and it aims to provide inspiration and practical guidance to representatives of universities, companies and public administration for the creation and development of innovation networks. The rate at which new knowledge and research results are absorbed by the economy sets the pace for the acquisition of permanent competitive advantages for both enterprises and regions. In Poland, low levels of knowledge transfer and technology commercialization have been identified. Currently many institutions are supporting entrepreneurs and researchers in the conception and implementation of innovation in Poland. The number of innovation institutions is still growing (Matusiak, 2010). Although these centers have an important role to play in building competitive advantage in the economy, they are weak and fragmented. Individual cells of the system: business, science, and R & D units all operate in isolation. Their ability to provide services for innovation, especially those that are highly specialized and world-class is still unsatisfactory. The Polish system of technology transfer and commercialization is poorly prepared for the challenges of globalization and European integration (Matusiak, Guliński, 2010). In all Polish regions there is a fragmentation of the innovation system. Individual centers, HEI[2]s and R&D institutions do not know each other. They do not cooperate, but rather compete for public funds and clients. In the wider innovation network a lack of trust and cooperation between actors is one of the most important problems facing the Polish system of technology transfer and the commercialization of knowledge.

Current understanding

A lack of cooperation between the science and businesses sector, and a need for cooperation are pointed to by many authors (Kondratiuk-Nierodzińska, Grabowiecki, 2004). There are many barriers to overcome in technology transfer, mainly because research organizations and the commercial sector have different aims and norms (Nelson & Byers, 2005), time frames, language (Trzmielak, Gwarda-Gruszczyńska & M. van Geenhuizen, 2010), and culture. Another barrier can be the weak absorptive capacity of the partners (Trzmielak, 2011). One of the indicated reasons is the lack of equity funds and the high costs of innovation. The influx of EU funds has already changed a negative image of Polish research centers and companies in the area of knowledge transfer. As indicated by Gwarda-Gruszczyńska (2013) there is potential for increased cooperation. However, the Polish innovation indicators and incomes of HEIs and R&D units only change very slowly. Research results obtained by the authors confirm constantly low levels of collaboration between researchers and entrepreneurs. Four out of five surveyed entrepreneurs declared no cooperation with the scientific community.

2 HEI – Higher Education Institution

On the other hand there is constant pressure on universities to work on applicable research and to focus their teaching and research efforts on ways that have a direct impact on their local regions. Regional and national economies pressure universities to become leaders in today's global market. The challenges posed by the market, associated with optimal knowledge transfer to industry and the conversion of scientific and technical knowledge into new products and services, all force a change in research units' approaches to cooperation with companies. Application of marketing concepts in the processes of commercialization of research results is important. References to science marketing called by some authors 'science to business' marketing can be found in the innovation management and technology transfer literature rather than in the marketing literature: Jolly (1997), Etzkowitz (2002), Bok (2003), Butler and Gibson, eds (2001), Markman et al (2005), Frischmann (2005), Shankar (2008), Baaken (2009), Baaken and Plewa (2009). The Polish literature on science marketing is very thin. Only few articles about marketing of research results can be found (Jasinski (1998), Pomykalski (2001), Bialon (2012)). According to Bialon (2011) R&D organizations do not run marketing research, do not segment market and have small knowledge about the demand for new technologies. Kruk writes about the marketing of product innovation (2012). Trzmielak & Grzegorczyk (2010, 2014) write about marketing for technology transfer and commercialization and the role of relationship marketing in fostering university technology transfer and commercialization. Relationship marketing is a wide marketing concept that has been described by many authors: Reichheld & Sasser (1990), Berry (1995), Grönroos (1994,1996), Gordon (2001), Gummesson (2002), Ballantyne, Christopher & Payne (2003), Kumar & Reinartz (2006), Storbacka & Lehtinen (2001), Otto (2004). Relationship marketing is conducive to the creation of innovative ideas and that is why it could also be helpful in fostering commercialization processes at research and higher education institutions.

Methodology

The following research aims have been identified:

1. To enhance the understanding of relationships between science and business in the process of knowledge transfer in Poland,
2. To conduct comparative analysis of Poland with other countries,
3. To identify required changes in the existing cooperation models of chosen industries,
4. To develop recommendations for improved relations between universities, R&D units and companies.

Direct and indirect methods of data gathering were used in the research including direct measurement (in-depth interview) and indirect measurement (e-mail survey). Two measuring instruments were created: a questionnaire and an interview scenario. The combination of direct and indirect methods provided both quantitative and qualitative data. First, in 2012 a series of in-depth interviews was conducted with Technology Transfer Office staff in each institution. Institutional interviews were also conducted with faculty and university top management. Institutions researched were drawn from among the 20 biggest universities in Poland. The aim was to identify barriers to, and drivers for, the knowledge transfer and university research commercialization system in Poland. Following this first step, an online survey was conducted focussing on a series of target groups: scientists and entrepreneurs (representing businesses) in a series of territories comprising: Poland, two developing EU countries (Czech Republic, Hungary), two developed EU countries (Norway, France), USA and Canada. The aim was to gather insights concerning factors for improving relationships between science and business. From April to August 2014 an online questionnaire has been sent by e-mail to 10 000 respondents from two target groups: scientists and business representatives in Poland, four EU countries and the United States.

We sampled purposefully, selecting respondents meeting chosen criteria for the study. This was a purposeful sample, in the sense it is not intended to be representative, but rather is likely to have the characteristics that we want to examine. Such sampling does not allow the results to be generalizable to the wider population but they may be generalizable at a conceptual level (Jack et al., 2008). We choose two European countries in a similar stage of development to Poland, two European well developed countries and USA to make some comparisons, to find differences and similarities and to learn lessons. The research population was created according to the criteria of institution: scientific research institution and enterprise from a chosen sector. The main interest of the scientists were in the sectors: biotechnology, information technology, energy and the environment, chemistry and food technology and new technologies. An additional criterion for the selection of companies was experience in cooperation with research centers and innovation. We used the lists and websites of research institutions, science and technology parks and technology incubators. The lists used recorded information about companies that the universities cooperate with. We also used published reports and rankings of most innovative companies. Scientist was defined as a person working in scientific research institutions (mostly high schools). A database of scientists was established on the basis of academic institutions data including universities registers, for example from the Ministry of Science and Higher Education and European Commission. The test results presented in this article, refers to the level of statistical significance below 0.05.

From the 10 000 sample we received 554 answers. The survey yielded a response rate of 5,54 %. After removing cases with missing data, the results presented here are based on a final N of 361 responses. Two out of three respondents represent business, while every second response represents Poland, every seventh East and Central Europe countries and West Europe countries 20 % of the questionnaires were submitted by American and Canadian scientists. While the views presented in this paper are imperfect representations of reality, and are not representative of, or applicable to, every academic discipline we believe that they are an important point in an ongoing discussion. That discussion seeks to understand the building of knowledge and competence in scientific and research centers and more effective and efficient processes of knowledge transfer especially in developing countries.

Findings

We have analyzed the factors that inhibit or intensify the integration of entrepreneurs and researchers. Analysis of a cross table revealing the relationships between scientists and entrepreneurs has focused on the ranking of characteristics of good relationship. We tested characteristics in two groups: structural and relational drivers and barriers. Three structural features were identified as significant: experience in cooperation; business orientation of HEI; and presence of business incubators in the region (Fig1).

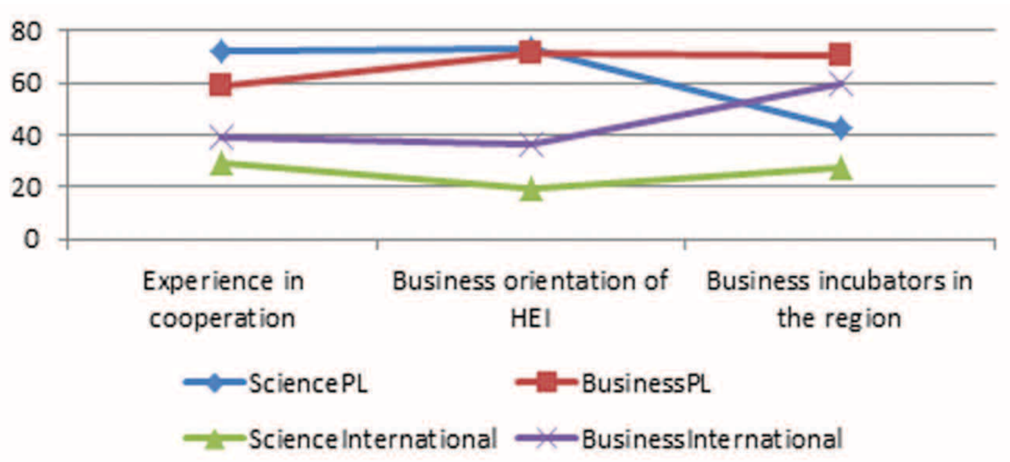

Figure 1: Factors mostly influencing the development of science-business relations (in percentage)

Source: own research

In the case of cooperation between universities and business it can be said that these activities involve interaction between individuals belonging to systems that are very different in their identity and mission. The results show that entrepreneurs, both Polish and from the other countries surveyed, envisage a greater role for business incubators in the region and their impact on the possibilities of cooperation with science than scientists themselves. It is interesting that Polish respondents attach greater importance to earlier HEI experience in cooperation and business orientation. This is particularly evident in the graph showing the international scene (Fig2). Brown and Oplatka (2010) indicate that Canada and the US deregulated the higher education market in nineteen-eighties. Canadian and US universities made efforts to gain a larger share of international research at the end of Twentieth Century. Poland started to change its low position in the scientific research area in 2005, introducing the obligatory regulation on intellectual protection and technology transfer office creation. The importance of Polish university business orientation follows the deregulation policies gradually introduced in Poland. It is widely assumed that in the context of increasing competition higher education institutions need to improve their market approach.

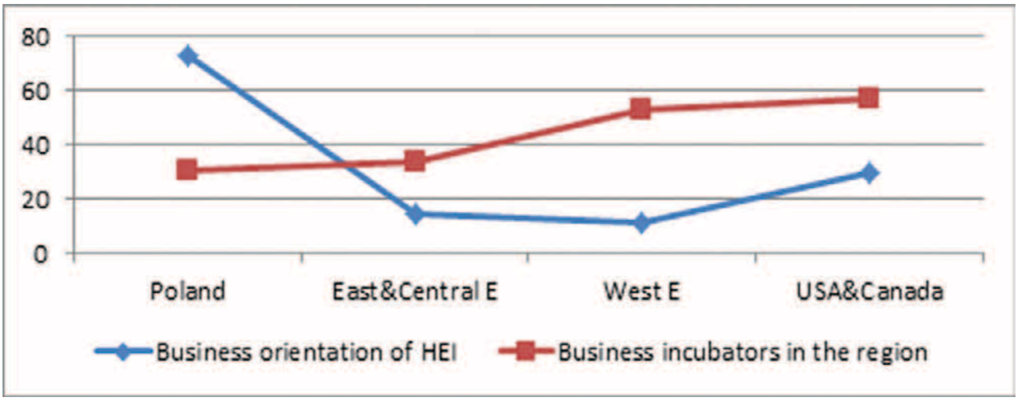

Figure 2: Factors mostly influencing the development of science-business relations – international perspective (in percentage)

Source: own research

Business incubators are also a new idea in East & Central countries. A significant growth in the number of incubators in Poland occurred at the beginning of nineteen-nineties. Their role in high-tech companies development still is small because of many barriers to start-up creation (Trzmielak,2011). Polish companies showed too little interest in technology transfer and the scale of the diffusion process for technology was too small (Jasiński, 2005). The Batavia Industrial Center (founded in 1959 by J. L. Mancuso) is recognized as the first US business incubator (Zehner, 2011). The economic impact on the region surrounding has been significant. Therefore the high influence of business incubators on science and business cooperation in the US, and by extension in Canada and Western European countries, is understandable (Matusiak, 2006).

A pretest of characteristics from the second tested group (relational drivers and barriers) suggested following relational attributes to be taken into consideration in the further quantitative research: scientist and entrepreneur activity in initiating relationship, communication, responsiveness for offer, openness for business and scientists needs, mutual trust, easy accessible and attractive offer, competence in collaboration. From the international perspective, six features were identified as being significant: active entrepreneurs in initiating cooperation; sufficient scientist responsiveness to the business offer; sufficient entrepreneur responsiveness to scientific offers; sufficient entrepreneur openness for scientists' needs; sufficient entrepreneur trust for science; and good communication skills of scientists (Fig3).

What can be noticed is that a proportionally larger group of American and Canadian respondents in the surveyed population referred to a significant role for entrepreneurs in initiating cooperation with science and sufficient responsiveness to a scientific offer. Every second US and Canadian respondent indicated that an active entrepreneur was a crucial market player in business and science alliances. Two out of five surveyed respondents emphasized entrepreneur responsiveness for scientific offers as being sufficient for cooperation. This was three times higher a number of respondents than is seen in Poland.

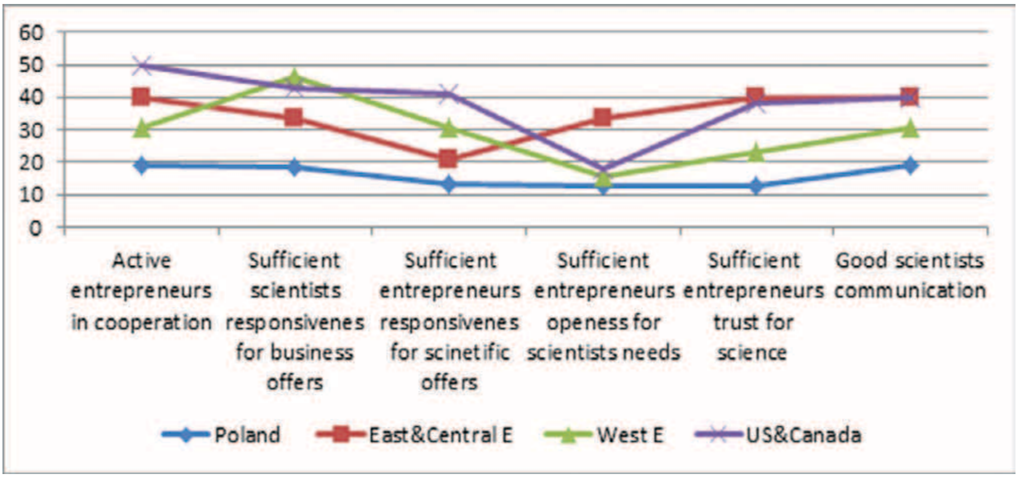

Figure 3: Essential drivers of good scientist entrepreneur relationship – international perspective (in percentage)

Source: own research

Proportionally more American and Canadian respondents confirmed the role of the six analyzed characteristic in the process of building good relationships than is seen for Polish, East Central European and Western European scientists and businessmen. Thus, the results show that respondents from developed countries (noting higher innovation rates) rate relational drivers as "essential". The results shows that Polish respondents underestimate the relational factors and their responses vary considerably from the reports of scientists and entrepreneurs from other countries.

Furthermore, the dependence between scientists, entrepreneurs and relationship drivers has been analyzed. We found the following four characteristics to be statistically significant for both target groups: activity of entrepreneurs; good communication skills of scientists; sufficient scientist openness for cooperation; and accessible entrepreneurs offer for scientists (Fig. 4). The first two attributes were indicated in the previous analysis (Fig.3). They confirm that entrepreneur activity can be a critical factor in building good relationship between science and business.

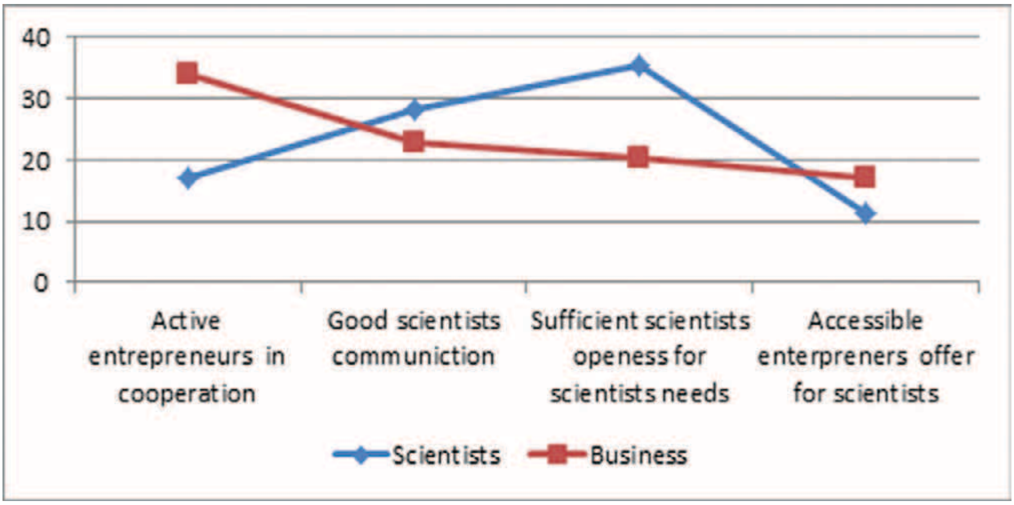

Figure 4: Essential relational drivers – perspective of entrepreneurs and scientists (in percentage)

Source: own research

Every third entrepreneur surveyed declared that in their opinion active entrepreneurs play a fundamental role in science and business cooperation. There were twice as many indications as those made by scientists. On the other hand, scientists indicated 'sufficient scientist openness to business offer' as essential (Fig. 4). Summarizing this part it can be stated that good relationships between scientists and businesses would be built based on two main characteristics: activity of entrepreneurs and scientists openness for business needs.

Finally, respondents were asked to rank characteristics of good relationships in the context of knowledge transfer and technology commercialization. The results show that both academics and entrepreneurs rank the existence of mutual understanding of each others' needs and commitment as essential drivers (statistically significant at the 5 % level or better). The feature "understanding each other' needs" has been reported mostly by respondents in the United States when "commitment" was most important for Polish respondents. Half of respondents rank the first feature as the first and second position on the ranking scale. Therefore it can be stated, following Statt's [1997] theoretical research on psychological approach, that the central dilemma for university organizations is that successful cooperation is likely to motivate entrepreneurs to be active in cooperation and encourage scientists to be open for business needs to work with.

The authors of the study identified following relational barriers, the analysis showed statistical significance (below 0.05):

- passive attitude of scientists to cooperation with enterprises,
- lack of openness of researchers to the business needs,
- no reaction of scientists to offers from businesses,
- low communication skills of researchers,
- lack of implications of scientific results in business activities.

The features presented are only a proposal for further discussion. Interesting observation came when considering perception of quality of research services offered by scientific institutions. Foreign respondents in both groups: scientists and entrepreneurs indicated similar perception of research quality (Fig.5) 19,2 % of scientists and 14,9 % of business representatives indicated that the quality of research offered by scientific organizations on market was very high and only few of them (0 % of scientists and 1,4 % of business representatives) think it to be of very low quality.

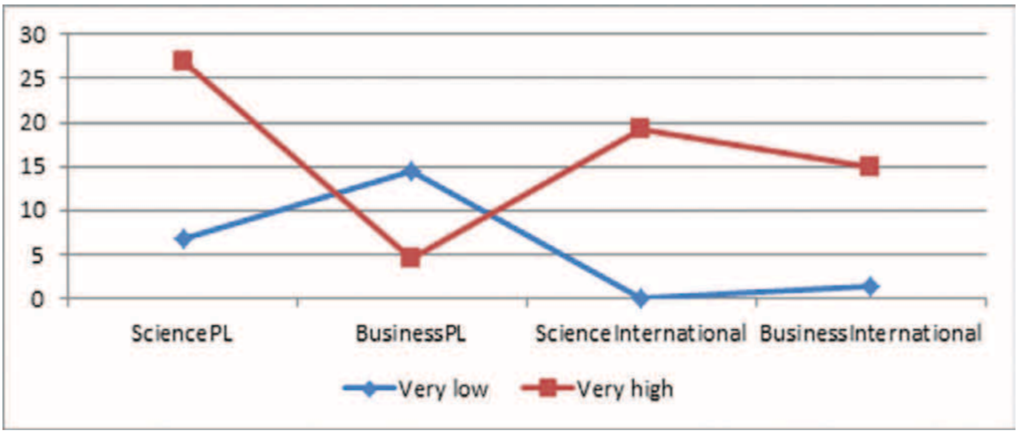

Figure 5: Perceived quality of research services offered by scientific institutions on market?
Source: own research

It looks like scientists perceive the quality of scientific services offered by HEIs slightly better than business representatives. The tendency can be seen also in Poland but the differences among both groups of respondents are much bigger. There is a considerable difference in group of polish entrepreneurs. Nearly 15 % of them perceive the quality of research offered by Polish scientific institutions as very low and only 4,5 % of business respondents from Poland indicated very high quality. Poor perceived quality may be one of the barriers of cooperation. It's important to mention the real quality of the research offered by particular institutions has not been studied, just the respondents perception of situation.

So, it can be noticed that:

- entrepreneurs perceive the quality of research offered by HEIs lower than scientists,
- the differences in perception of research quality among both groups: scientists and entrepreneurs are especially big in Poland,
- Polish entrepreneurs perceive the quality of scientific research offered by Polish HEIs as very low.

From a branding theory perspective consumers (here entrepreneurs as a university target group) may have difficulty forming their quality evaluations and may end up basing them on considerations other than their own experience. Thus, if there is a gap between reality and perception for different stakeholders then research universities should employ a range of brand elements to enhance brand recall and signalling. They should design corporate communication programs and communicate strong organizational associations. Other researchers have identified number of dimensions influencing perceived service quality: tangibles, reliability, responsiveness, competence, trustworthiness, empathy, courtesy and communication (Keller, 2008). For sure research universities and institutions need more integrated marketing communication to build image, awareness and trust among different groups of stakeholders.

According to Bennetzen–Moller (2013) the technology transfer activity of universities requires a special marketing approach – different even from business-to-business model. The university as knowledge creator has specificities that cannot be captured with sufficient precision through the marketing models applied to business models. Jasinski presented the whole concept of the marketing of R&D and innovation and was writing about marketing communication of scientific achievements as an element of public innovation policy (1998b) and communication with society (2010). He found out that the experience gained by public organizations and institutions with science marketing addressed to the business sector in Poland is so poor that science-to-business marketing is still in its infancy (2014).

Conclusions

Cooperation between companies and scientists can bring a significant increase in research leading to the introduction of new products. More ambitious research aims, higher risk, and more complex networks of interactions create specificity of the university-business relationships. In the context of the specific nature of these relationships all elements building mutual trust, commitment, and understanding of each other needs will positively influence the development of relations between the academy and business. The research shows that respondents from developed countries (with higher innovation rates) regard relational drivers as essential. Polish respondents underestimate the relational factors and their responses vary considerably from the reports of scientists and entrepreneurs from other countries. They concentrate more on legal and transactional mechanisms of cooperation. The research also shows that entrepreneurs perceive the quality of research offered by HEIs lower than scientists do. Most Polish entrepreneurs perceive the quality of scientific research offered by Polish HEIs as being very low. Other researchers (Tomaszewski, 2014) found that innovation cooperation between universities and industrial companies is most probable when the HEI is connected with the Polish Academy of Sciences (the most trusted research institution in Poland). It confirms the existing crisis of trust to public research universities in Poland. In the context of technology transfer and commercialization there is a strong need to rebuild the image of Polish science among different groups of stakeholders, especially entrepreneurs. The research results also show that good relationship between science and business should be built on two main characteristics: activity of business representative and scientist's openness for business needs.

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What Has Changed in Europe after the European Research Area and Times of Increased Uncertainty?

Challenges and Opportunities for Science, Technology and Education Policy

Manuel Heitor

Center for Innovation, Technology and Policy Research, IN+,
Instituto Superior Tecnico, University of Lisbon, Portugal
http://in3.dem.ist.utl.pt/

Abstract

This paper discusses new cumulative data on R&D expenditure and the qualification of human resources across Europe, taking a wide international comparison after a decade hit by recession and economic and budgetary problems. It aims at providing the necessary evidence for a revisited policy framework giving priority to knowledge and technological change across entire Europe. While debating the role of public policy in the continued modernization and transformation of our societies in an increasingly competitive world, the paper shows an increasing internal divergence on knowledge investments across Europe, beyond the increasing gap between Europe as a whole and North America. As a result, the paper argues that new paradigms and conditions for responsible science and innovation policy across EU require the *collective action* of R&D institutions and a system approach to higher education, together with new initiatives towards international cooperation.

Analysis shows that chronic backwardness in science and technology in many European peripheries, including in EU southern and eastern regions, have been significantly overcome over the last decade. Nevertheless, their growing scientific and technological capacity is now associated with an increasing vulnerability as a result of the growing international competition to attract qualified human resources. Additionally, the comparative analysis of levels of economic diversification and sophistication across Europe, suggests the need to insist on qualification and institutional strengthening. This should consider active public policies to attract and retain qualified human resources, as well as considering public actions towards promoting new markets. The way in which the economic fabric may gain competitiveness and access to external markets may require enhancing the degree of internationalization of the scientific community and encouraging international R&D and advanced education partnerships.

1. Introduction: an increasingly diverging Europe

In a decade hit by recession and economic and budgetary problems, which public policies for science, technology and education are necessary in the near future, both for individual member states as well as the EU as a whole?

This question is relevant because it has become a common place to argue that science and technology permeates everyday life, but a new debate is emerging about the related role of the State, with emphasis in Europe (Mazzucato, 2013). The continuous need for growing investments in formal knowledge activities by countries and firms (Aghion, et al., 2009), underlines the search for competitive advantages and the establishment of sustainable bases for further development of the required "smart specialization" for Europe (Foray, 2009; 2015). This trend often combines mixed patterns of competition and collaboration (Bengtsson and Kock, 2000) and, in the specific case of Europe, is growingly intertwined to face a fast-paced, globalized and uncertain world (e.g., Owen et al., 2012; Stilgoe, et al., 2013).

In particular the current economic situation has had major implications on emerging policy discussions throughout Europe on whether or not to cut future investments in the realms of science and (higher) education (e.g., Heitor at al., 2014). This question has driven the creation of "step4EU – Science, Technology, Education and Policy for Europe" (http://www.step4eu.org/), a European wide network aimed to foster the systematic observation of issues in science and technology, higher education and public policy in Europe based on in-depth research. Its rationale derived from the observation that the quasi stagnation of R&D public investment in Europe over the last decade, which now accounts for about 2.0 % of EU's GDP (for comparison, GERD in the US is about 2.8 % GDP), hides a major trend of internal divergence inside Europe itself. For example, in the year 2000, Germany and France presented similar national R&D budgets; today, Germany outpaces France by 50 %. Italy budgets have declined since 2007, and in real terms are 15 % lower than in 2000. And, most of small countries have slowed down, or cancelled, previous increases in R&D budgets. This debate has emerged as a result of the deep international crisis that has been affecting Europe (e.g., Mazzucato, 2013) and to which many analysts, scientists and scientific organizations have turned their attention, in several European regions, with special emphasis on southern European countries.

Undoubtedly there was progress in Science, Technology and Higher Education throughout Europe, but as a whole, Europe has met neither its goals nor its promises in this area (EC, 2014). It is under this context that the research hypothesis driven this paper is that the new paradigms and conditions for science and innovation policy across EU require the *collective action* of R&D institutions and a system approach to higher education, together with new forms of international cooperation, as also discussed by Heitor (2015).

The challenges for Europe are immense, independently if they are global, national or local in nature, as most are to all effects transversal (e.g., global warming). An adequate policy framework not only helps mediating the interface between science, education and society, but also contributes to shaping systems, strategies and development patterns (Stilgoe, et al., 2013). Ultimately, the question is how to avoid the surprising estimates of UNESCO (2012), that warns about the possibility to have a "lost generation" of 200 million of young people – the bulk of which are expected to possess some kind of higher education qualification.

In addition, for Europe to meet the challenges of the Rome Declaration, signed in November 2014 by European Ministers responsible for science, inviting all the higher education and research institutions across Europe to incorporate Responsible Research and Innovation (RRI) as a key scientific attitude, there is the need of an adequate policy framework at EU and national levels. Although the idea of "responsible science" seems relatively consensual, it raises new theoretical questions about the growing trend in recent decades to enhance the economic appropriation of the scientific activity (Owen et al., 2012). It also questions the freedom of learning and research, as well as the "political appropriation" of science and, above all, requires deepening current knowledge on the "pathways of excellence" in scientific and higher education activities (Stilgoe, 2014).

These issues, among many others that could have been listed, recall similar debates in the eighties, as associated with overcrowding among students, lack of resources, increased costs of the school places, maladjustment between the educational and productive systems and the slow speed of response to labor market demands in the educational response (Coombs, 1985).

In that occasion, it was clear that investments in education were important drivers of economic and social development (Gilead, 2012). Indeed, investing in education in

Europe, and elsewhere, contributed to develop new capacities and skills, together with professional competencies that mitigated negative effects of cyclic crisis. The flexibility in addressing economic and societal dynamics has been facilitated and stimulated through science and education (e.g., Robertson, 2005; Selwyn and Brown, 2000), although many authors have argued that in the absence of a coherent policy framework (including collaborative arrangements, quality assurance procedures and other feedback mechanisms, among other issues) science and education are necessary conditions but not sufficient for wealth generation. In addition, analysis has also shown that budgetary cuts in science and (higher) education over time have exacerbated economic inequality and social exclusion (OECD, 2012).

In this context, scientific and higher education institutions are critical agents given their privileged locus as repositories of knowledge, skills and competencies, as well as their effective contributions to the economy. Thus, the current economic situation presents a strategic opportunity for revisiting the role and mission of advanced training, knowledge and innovation in a post-financial crisis in Europe. This requires the adequate and systematic observation of policies and budgets across Europe in a way to report, publicly and periodically, relevant information and early warnings on the state of policies and budgets in each country and at EU level.

This paper follows previous studies (Heitor et al, 2014), which address four priority aspects: first, the paths for a new industrialization pattern that is required in order to encourage socioeconomic resilience approaches (e.g., McKinsey Global Institute, 2012); second, the need to insist on persistent and informed investment policies in science and technology, sustained in demanding ways of promoting scientific and technological culture in society, and the social appropriation of knowledge; third, qualification and learning, in a context of democratization of access to knowledge and innovation that we must safeguard and go on demanding, which call for enduring efforts of modernization and openness of higher education, preserving the social function of higher education graduates (Heitor and Horta, 2014); and fourth, the internationalization of higher education in association with active public policies to sustainable and long term cooperative ventures with international partners (Heitor, 2015).

Section two presents a summary of data and figures regarding the evolution of investment in science and technology in Europe over the past decades. Section three provides new sets of data regarding knowledge investment accumulation and its relative impact in advanced education for human resources in several European countries. Section four discusses the results, putting the evolution of national public policies in S&T into perspective. It starts by linking public investment in science and technology to the systematic reinforcement of human capital and includes the discussion of the impact of S&T policies on the economy in view of the diversification and internationalization of several European countries. Finally, the paper concludes with a short summary.

2. Data and Facts: the dynamics of the investment in science and technology

Figure 1 extends the data published a few years ago by UNESCO (2010; for 2002–2007) for the period 2002–2012 and compares the world shares of GDP and of GERD (Gross expenditure in R&D) for the G20 for an entire decade. It is important to note that the most dynamic economies (including USA, Germany and China) keep increasing their gross expenditure in R&D and, above all, are characterized by a world share of GERD higher than their world share of GDP. The most notable figure is that of China, that has increased over the decade under analysis its world share of GERD from 5 to 15 %, surpassing its world share of GDP. On the other hand, Europe as a whole decreased the world share of GERD from 30 % to 23 %, while its world share of GDP decreased from 31 % to 22 %. For comparison, US keeps a much larger difference between its world share of GERD (32 %) and its world share of GDP (19 %), which may represent a proxy for the critical importance of investing in knowledge production and diffusion.

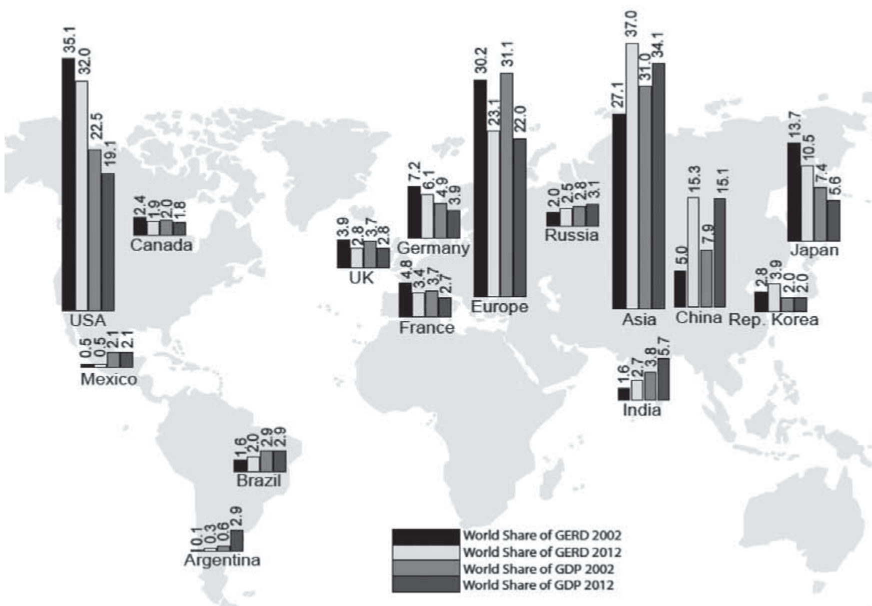

Figure 1: World share of GDP and GERD for the G20 over the last decade (2002–2012); values in %

In relation to the relative European competiveness in relation to other parts of the world, Figure 1 also shows the quasi-stagnant levels of R&D investment in Russia and South America, albeit with some noteworthy national initiatives. For example, gross expenditure in R&D in Brazil has not been able to surpass 1.3 % of GDP, and in Argentina it is kept as low as 0.6 %. Overall, the South America region lags in R&D capacity, with Brazil appearing to have under-performing expectations, with 1.6 fewer publications (in the Science Citation Index) by million inhabitants than Chile, and 5.5 than Germany.

In terms of political action, science policy is undertaken through annual appropriations for Science and Technology (S&T), which are approved each year by national parliaments within the context of state budgets (i.e., "GBOARD – Government Budget Outlays or Appropriations of R&D", in technical nomenclature). Looking back to what the evolution of the European scenario has been over the last two decades regarding budget appropriations for S&T, Figure 2 shows that, in 1995, France and the northern European countries had the largest appropriation per capita for S&T. By contrast, over the 2000–2009 period, in line with an increase in the German budget allocated to S&T, which grew by 60 %, there was a relative stagnation of the French budget after a 12 % decrease between 2005 and 2007. During that period (see, for example Gago and Heitor, 2007), some small and medium-sized European countries increased their investment in S&T, particularly Portugal and Ireland (which almost tripled their budget) and Finland and Belgium (about 1.6 times more).

Figure 3 quantifies the detailed evolution of the various national budgets allocated to S&T and the analysis shows that, in 2012, Germany, the Netherlands and mostly northern European countries allocated the largest annual budgets per capita to S&T. The picture that emerges is characterized by an increasingly large divergence at national level within Europe (EC, 2014), mostly after a decrease in all annual budgets between 2009 and 2012, with the notable exception of Germany. In other words, 10 years ago, France and Germany were characterized by similar budgets allocated to Science and Technology (Figure 3 b), whereas today the French budget has been reduced to around 60 % of that of Germany. Over the same period, the UK's budget allocated to S&T was reduced by more than 10 %, Italy cut its S&T budget by 15 %, and Spain by 17 %. These cuts at national level are associated with a relatively stagnant overall European budget throughout the decade, despite some important initiatives, including the creation of the "European Research Council" in 2005. This was the result of joint efforts from scientists and their most influential organizations across the continent, as recently discussed by Celis and Gago (2014).

It is important to note that Germany is the only EU country that continued to increase its S&T budget, even in times of crisis. From 2013, Germany's S&T budget has been similar to that of France and the UK taken as a set. By contrast, only Germany and northern European countries have met the European targets for R&D expenditure, which were set at 3 % of GDP (EC 2014).

In order to understand the situation in Southern Europe, it is interesting to look at the specific case of Portugal. Its annual budget for S&T only reached 1 % of GDP in 2008, despite the expectation that this figure could be achieved in the 1980s (see, for example, Gago, 1990). It was only about 0.5 % in 2000 and 0.8 % in 2005, accounting for nearly 3 % of the overall public budget only by 2011 (Heitor and Bravo, 2010; Heitor et al., 2014). It therefore increased by 33 % in relation to GDP between 2005 and 2011 and by 23 % in relation to the global State budget. In Europe, only Estonia, Luxembourg and Slovenia grew at a higher rate during that period.

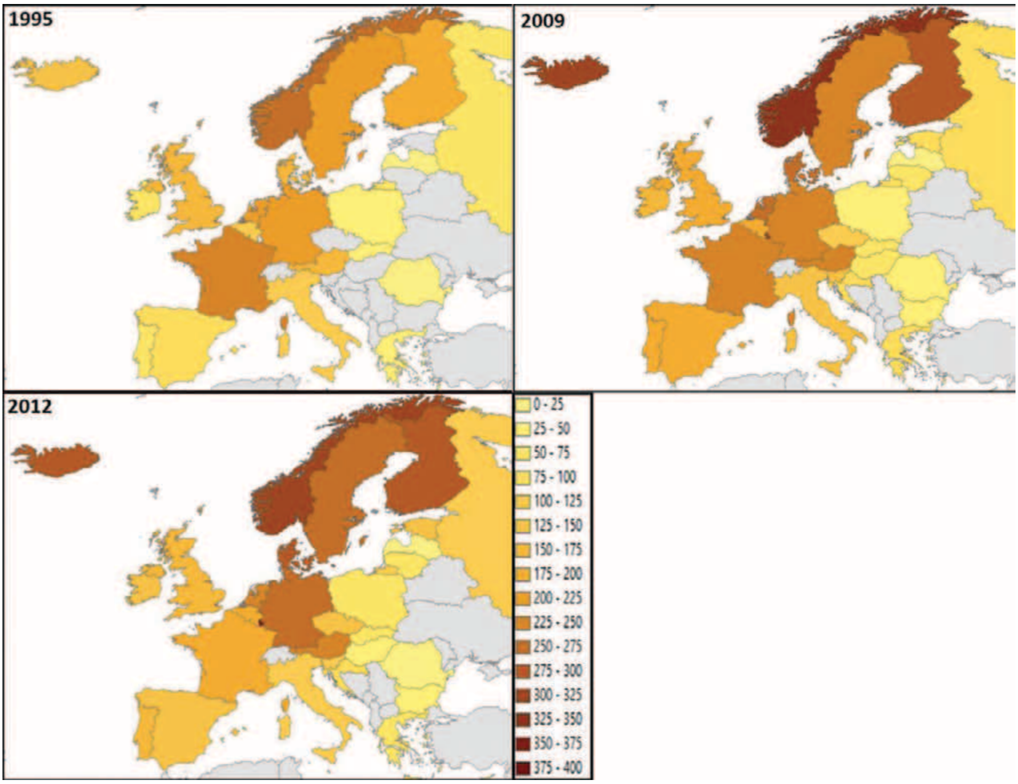

Figure 2 – Evolution of "Government Budget Appropriations or Outlays for R&D"; GBOARD)/capita) in Europe for 1995, 2009 e 2012 (values corrected for "Purchasing Power Standard, PPS", per inhabitant in 2005, at constant prices).
Source: EuroStat.

In Portugal (as well as in Spain, as discussed by Núñez, 2013), however, there has been in recent years a decrease in the budget allocated to S&T, associated with the perception that policies must be changed. In this regard, two types of arguments have been put forward, which are often conflicting to each other and may result from distinct political influences (Gago, 2014). On one hand, there is a recurrent argument in Portugal for targeting public support to companies and mostly to business competitiveness, and, on the other hand, the need for increasing selectivity criteria of public support based on the claim of overqualified personnel. This has resulted in the reduction of the share allocated to advanced education (i.e., reduction of doctoral and post-doctoral scholarships funded by the Portuguese Foundation for Science and Technology, FCT) and scientific employment (i.e., ending a large majority of PhD researcher contracts, directly supported by FCT).

Figure 3: Government Budget Appropriations or Outlays for R&D (GBOARD), 1981–2012.
Source: OECD.

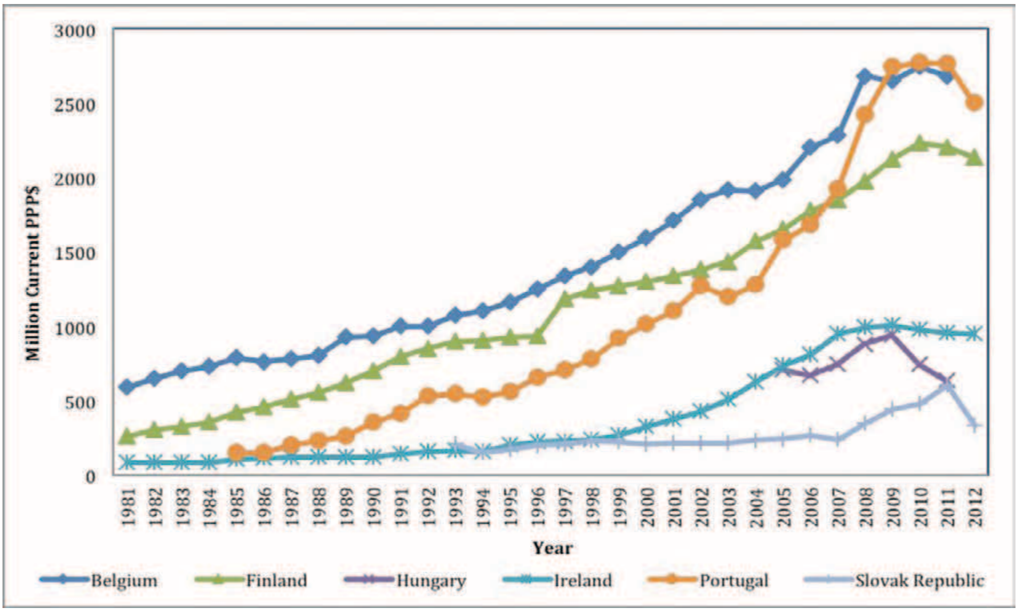

Figure 3a: Sample of small and medium EU Countries.

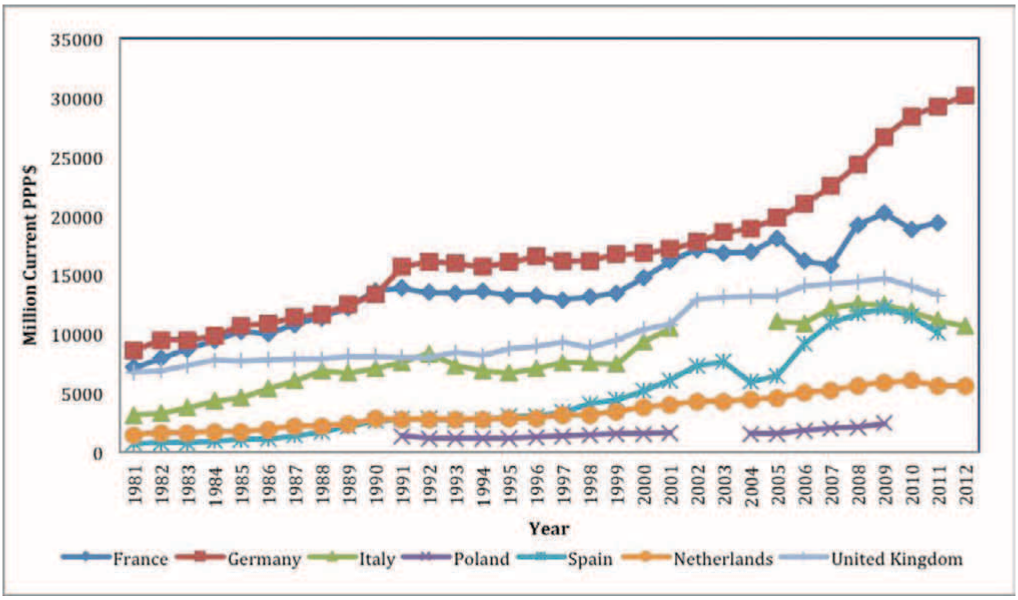

Figure 3b: Sample of large EU Countries (Netherlands is included because of the size of the budget).

As a result of these policies, the level of support for attracting young researchers from abroad to work in Portugal has been considerably reduced. Besides, the brain-gain effect, which had finally took place in 2009 after so many decades of outflows of talents, has probably faded away (i.e., brain-drain, as discussed in detail by Heitor et al., 2014). The argument of overqualified personnel and the related reduction of the level of support for advanced education have re-emerged the debate on the sustainability of doctoral and post-doctoral studies in Portugal, in a context of growing international competition for qualified human resources (OECD, 2012; Stilgoe et al., 2014; Heitor et al, 2015).

Despite the lack of accurate data on the migration qualification structure, Figure 4 shows the substantial growth of migratory flows from Southern to Northern Europe since 2010, mostly of qualified young people (OEm, 2014). The respective impact on the reduction of the scientific and technological capacity in Southern European countries and regions is not dully quantified or described, but has been recurrently debated by the scientific and academic community.

Still regarding Portugal, one of OECD's last reports regarding the status of science and technology at international level, OECD (2012), identifies three fundamental aspects that characterize the development of the country's scientific and technological capacity in recent decades. First, the OECD recognizes the Portuguese progress in scientific output, with publications in the top-quartile journals per GDP, similar to OECD average. Second, industry-financed public R&D expenditure per GDP and businesses in particular, remains well below OECD average. Third, the base of tertiary education of working population, considered as a whole, is still considerably below OECD's average levels (i.e., "adult population at tertiary education level").

Understanding these aspects is critical to help shaping the terms that must govern responsible science and technology policies throughout Europe for the coming decade, mostly if analyzed in comparative terms at international level. In this regard, the paragraphs below aim to discuss critical issues associated with the formulation of science policies in Europe for the next decade, considering the specific nature of each country and national system and taking into account the dynamics of scientific capacity depending and the related accumulation of investment in recent decades (e.g., Ziman, 1978; Conceição and Heitor, 2002).

Figure 4: Flows of people from Southern to Center and Northern Europe, 2005–2013

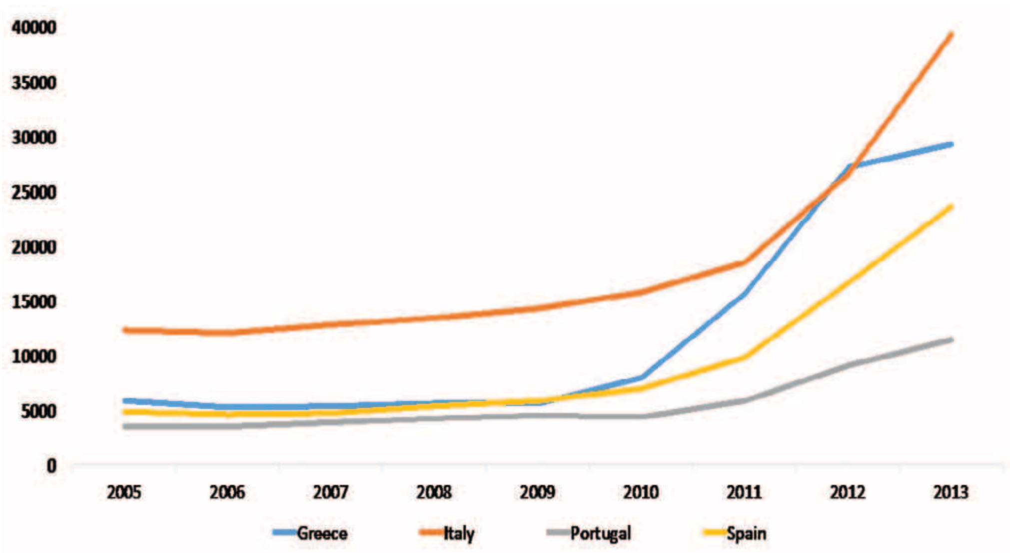

Figure 4a: Number of people entering in Germany by country of origin, 2005–2013

Source: Statistisches Bundesamt Deutschland, Fachserie 1 Reihe 2- 2005 a 2013

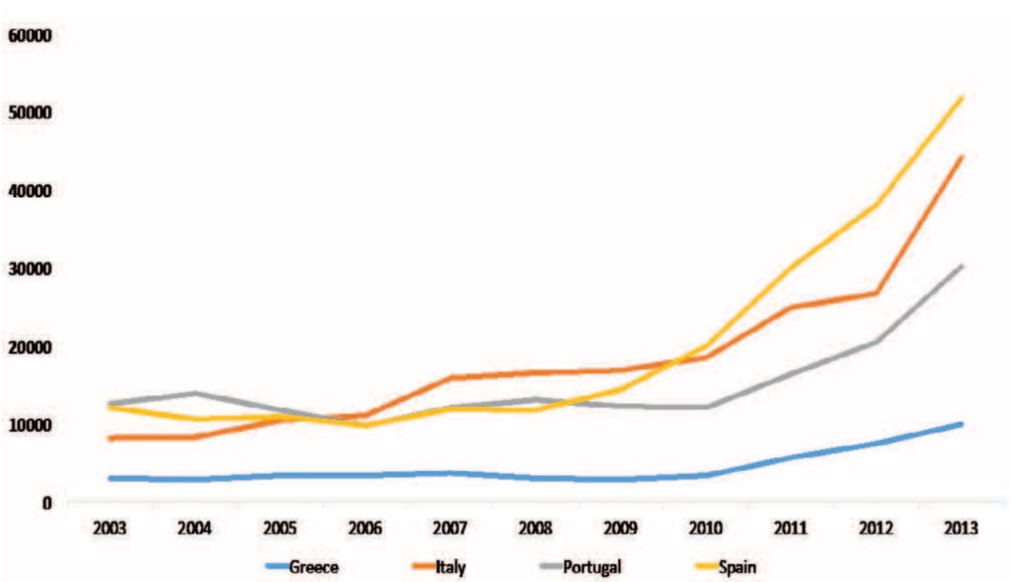

Figure 4b: Number of foreigners in UK with a "National Insurance Number", by country of origin, 2003–2013

Source: Department for Work and Pensions – UK

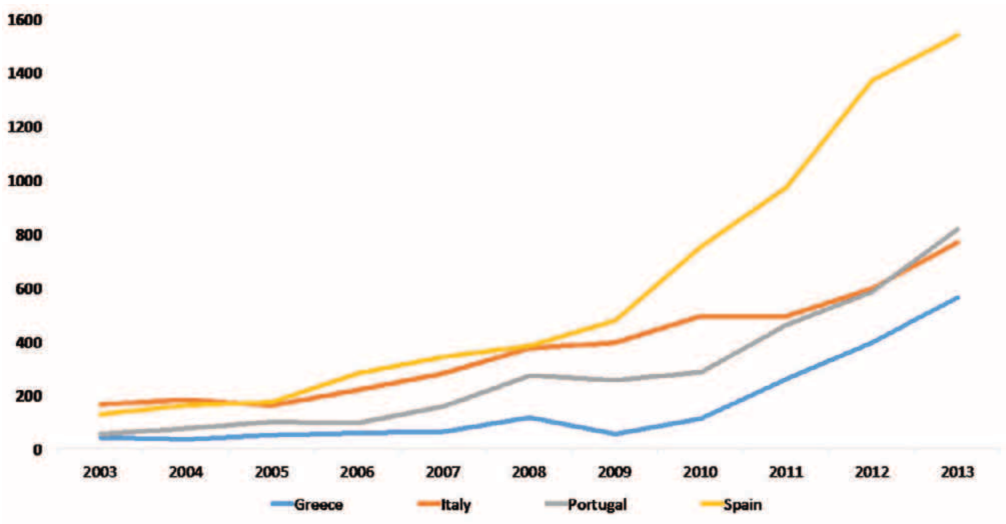

Figure 4c: Number of people entering Norway, by country of origin, 2003–2013
Source: Statistics Norway, Immigration, emigration and net migration, by citizenship.

3. Analysis: the accumulation of investment in knowledge and its impact on human resources

The essentially cumulative nature of knowledge and the dynamics associated with investing in that knowledge has served as a basis for the conceptual definition of the terms that may address the theoretical formulation of knowledge-based societies (e.g., Lundvall and Johnson, 1994; Romer, 1994; Ziman, 2000; Nowotny et al., 2001). It is within this framework that the comparative study of science and technology systems and the social construction of knowledge (Bijker et al., 1987) calls for a better understanding of the levels of accumulation of R&D expenditure over a number of years, which is of course conditional on the performance of those systems (e.g., Conceição et al., 2004).

Figure 5 attempts to introduce this discussion by comparing the accumulated investment per researcher in Europe and Norte America over the last three decades (with reference to 1982) and shows levels of investment in Europe 50 % lower than in the USA by 2012. Analysis also shows that the average investment in R&D per citizen in Europe has decreased comparatively to that in USA. The question that arises is about the diversity of political options in Europe as a whole and at the various European member states that have allowed this overall situation. The following paragraphs attempt to clarify this discussion through the analysis of sets of cumulative data.

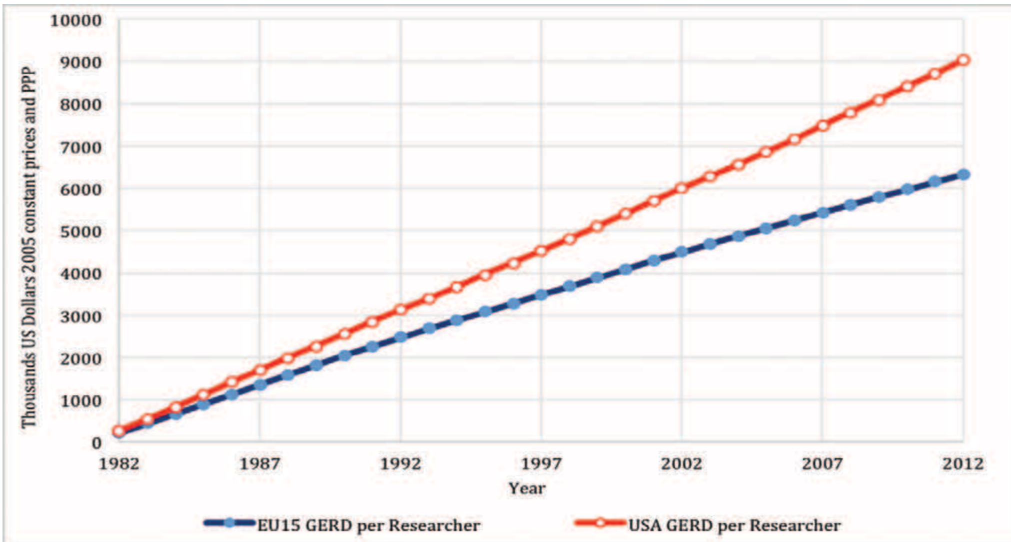

Figure 5: Cumulative R&D expenditure per researcher, as integrated over the period 1982–2012 (U.S. Dollars 2005 constant prices and PPP).
Source: OECD.

3.1 The accumulation of investment in knowledge

Figure 6 compares annual data with the accumulation of global R&D spending per capita in the last 30 years for an extended sample of European countries. In absolute numbers, at least since 2008, a larger R&D divide is occurring in Europe, with a growth of resources in Germany and some Nordic countries, against a relative global reduction of resources in other large countries like Spain, Italy, France and the UK. For the smallest countries, the case of Portugal is again worth mentioning. In 2012, Portugal's expenditure per capita was roughly one third that made by the UK and less than a quarter of the typical values for Germany or the northern European countries. Despite the impressive growth in the last 30 years, with R&D expenditure increasing five times more than GDP, aggregate indicators still stand substantially below those in any other Southern European regions and lag considerably behind those of Northern Europe.

Given the debate that has re-emerged in Southern Europe (among other European peripheries) regarding the size of investment in science, we should first point out that the accumulation of investment in S&T over the last 30 years is indeed in a lossmaking situation, in a way comparable to all other European regions, which accounts for 1/3 of the European average in per capita terms. On the other hand, Europe shows tremendous internal diversity with an aggregate expenditure per researcher that stands roughly 50 % below that made by the US.

Figure 6: Annual data and cumulative evolution of R&D expenditure per capita along 30 years in sample of EU countries, 1982–2012 (USD 2005 constant prices and PPP);
Source: OECD.

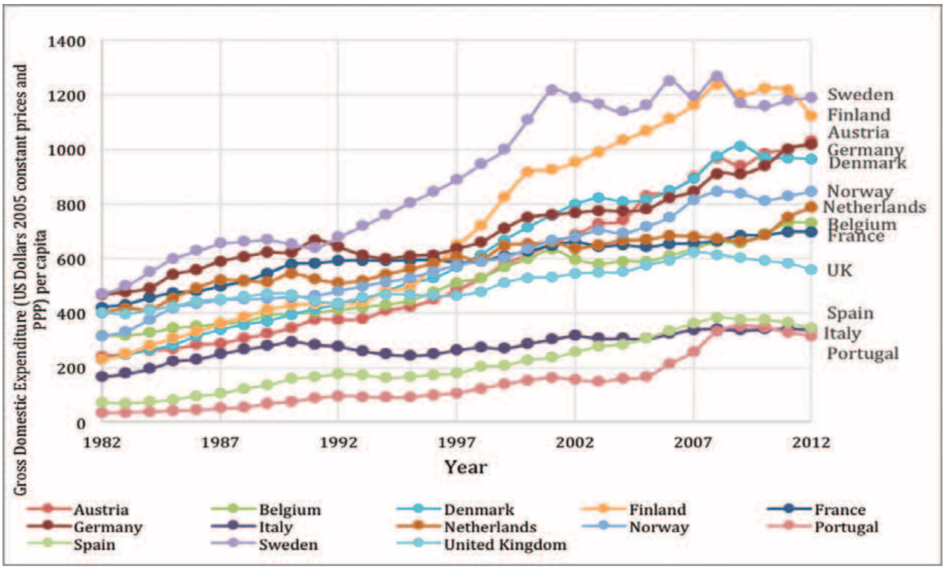

Figure 6a: Annual evolution of GERD/capita in sample of EU countries.

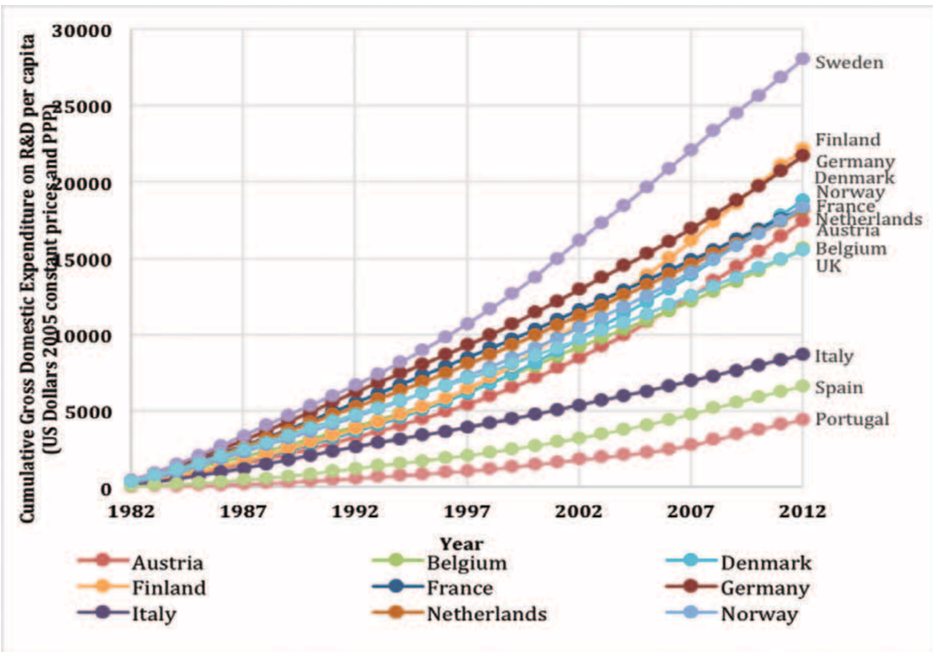

Figure 6b: Cumulative R&D expenditure per capita with

reference to 1982 in sample of EU countries.

3.2 The impact of S&T policies on advanced education of human resources

In the context of the previous indicators, it is reasonable to ask the question, so what has changed in Europe in the last decade? In addition to the number of graduates in Science, Technology and Mathematics per 1.000 inhabitants (Figure 7), where European peripheries (and Southern European countries in particular) underwent the most significant changes within the framework of the OECD, the reinforcement of education and qualification of new resources and their institutional integration, along with the attraction and retention of researchers from around the world, are confirmed as a distinct feature of some of those countries (e.g., Slovakia, Poland, Czech Republic, Romania and Portugal).

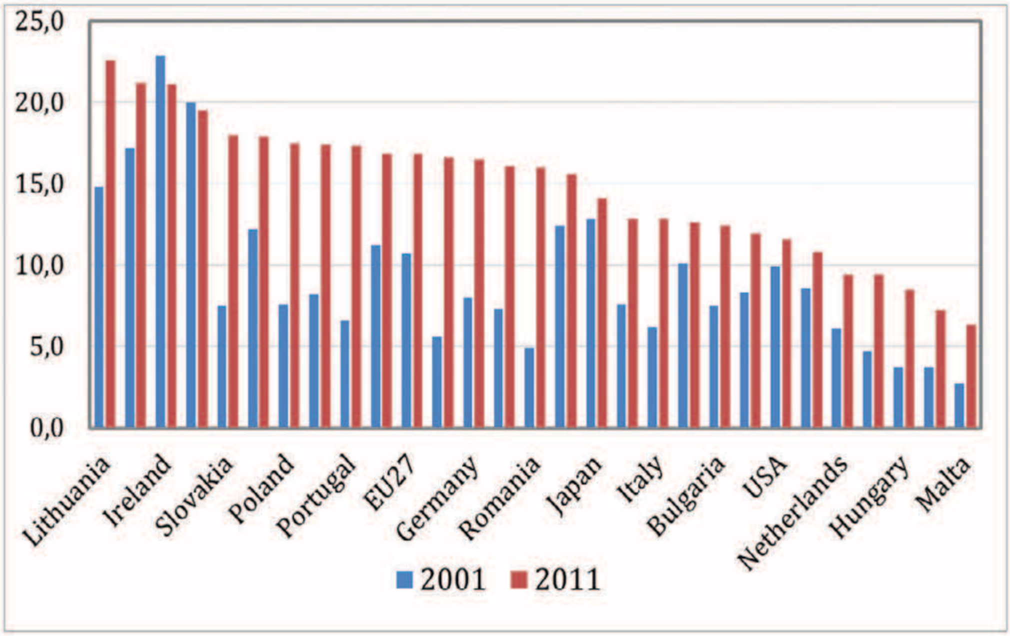

Figure 7: STEM graduates per 1000 inhabitants with 20–29 years old in a sample of EU countries and the USA, 2012.

Source: EuroStat.

For example, in Czech Republic and Portugal the number of researchers in working population grew by about ten times between 1982 and 2012 (namely from 0.92 to 9.23, in terms of the number of researchers per thousand working population in Portugal). For example, about 45 % of researchers are women in Portugal and the number of researchers in companies is already about a quarter of the total number of researchers in Portugal (it was less than 10 % in 2000, and now exceeds ten thousand researchers in FTE). In addition, advanced training of human resources, as measured in terms of new PhDs per 10.000 inhabitants (Figure 8) has considerably improved throughout European peripheries.

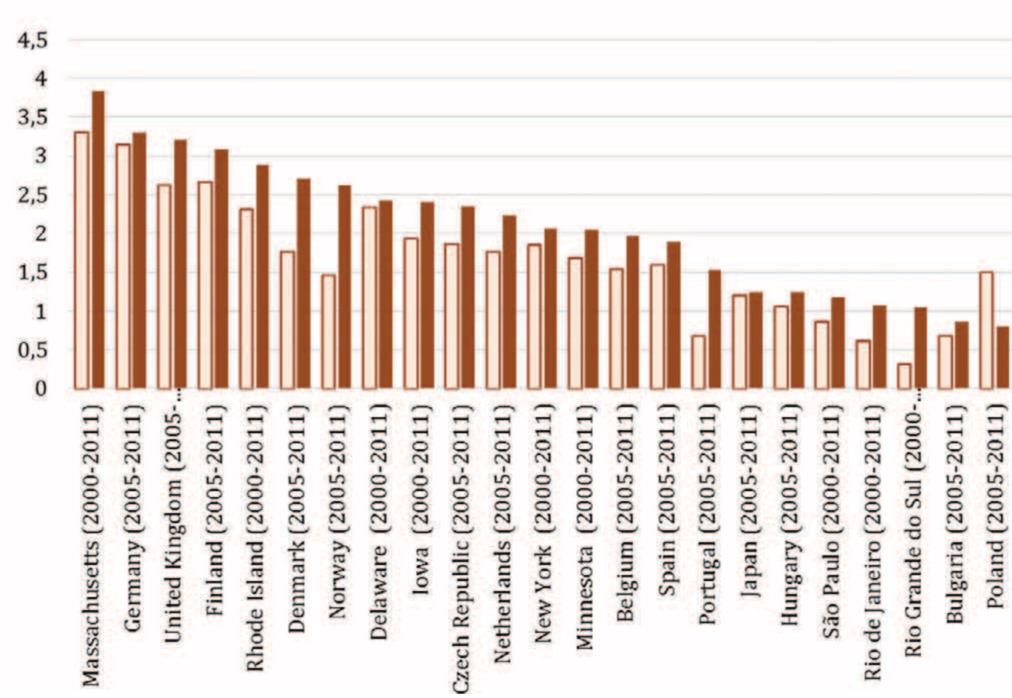

Figure 8: New PhDs per 10.000 inhabitants for 2000/2005 and 2011 in a sample of EU countries and (North and South) American regions.
Source: EuroStat; UNESCO; INEP; NSF; IBGE; NBS; SSB.NO.

Nonetheless, this scenario contrasts with the levels of qualification of population when measured in working population. Figure 9 quantifies the evolution of the percentage of working population (aged between 25 and 64) with tertiary education in science and technology fields or of those with a professional activity in which qualifications in science and technology are usually claimed to be held (i.e., “Human Resources in Science and Technology” or “HRSTO” in technical literature), which shows a considerable a persistent deficit in Southern and Eastern European regions over the last decade. For example, whereas in the United Kingdom, the Netherlands, northern European countries and in Europe’s most industrialized regions the HRSTO accounted for more than half of the workforce, that percentage in most southern and Eastern European regions remains below a quarter of the workforce (namely 24 % in Portugal in 2012).

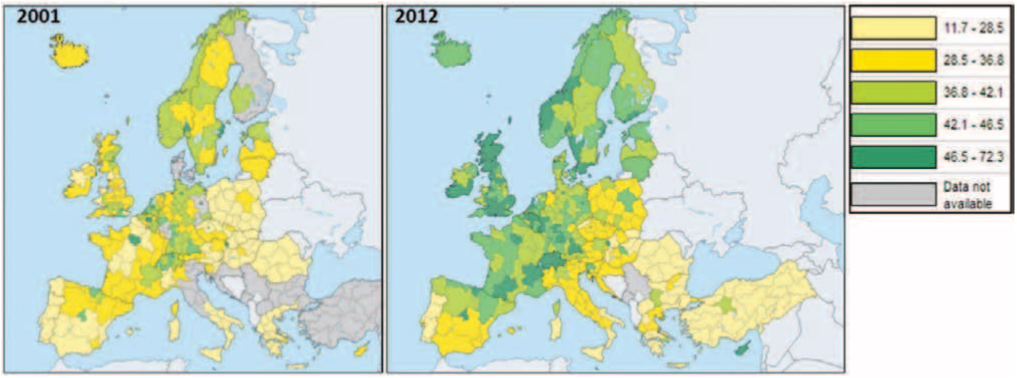

Figure 9: Human Resources on S&T ("HRST") in 2001 and 2012 (percentage of active population);
Source: EuroStat.

We must therefore try to find out the relationship between the R&D effort and the qualifications of human resources and where Southern and Eastern European stand in view of the European path as a whole.

Figure 10 relates the development of total HRSTO to the accumulation of gross expenditure in R&D over the last decade, showing that R&D investment efforts in many EU countries, including Hungary, Czech Republic and Portugal (as small and medium EU countries, Figure 10a) and Spain, Poland and Italy (as large EU countries, Figure 10b) were particularly used to qualify people. Nevertheless, those investment efforts still remain relatively tiny, compared to other small and medium-sized countries. For example, Norway, Holland and Finland have made considerably higher accumulated investment efforts in R&D than those "less mature" countries and are characterized today by a comparatively highly qualified workforce.

Figure 10: Human Resources in S&T (core coverage) versus cumulative gross expenditure in R&D, GERD (1998–2005);

Notes: HRST in percentage of total employment, GERD per capita in U.S. Dollars 2005 constant prices and PPP; HRSTC – Core refers to those people who have successfully completed education at the third level (HRSTE) – ISCED levels 5 and 6 and are employed in a S&T occupation (HRSTO) – ISCO major groups: 2 (professionals) and 3 (technicians); Source: OECD, EuroStat.

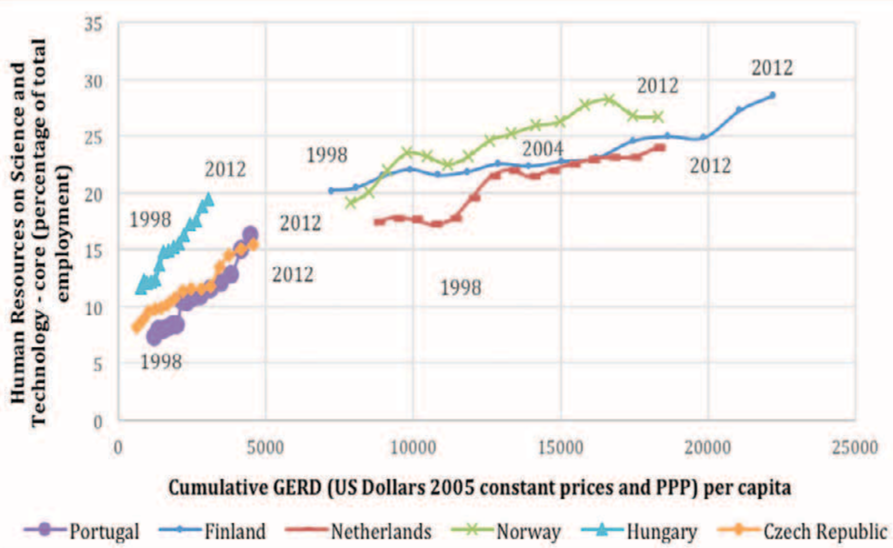

Figure 10a: Sample of small and medium EU countries.

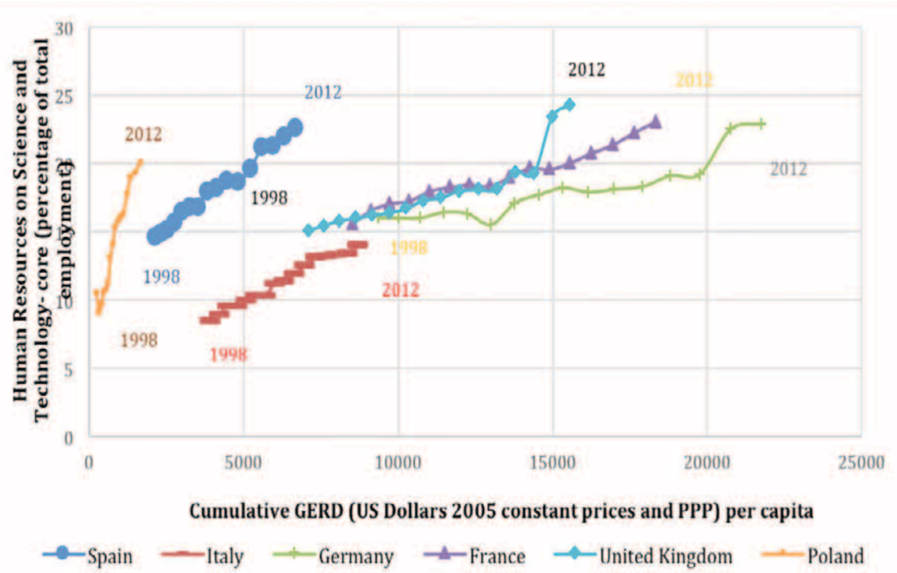

Figure 10b: Sample of large EU countries.

Within this framework, our analysis suggest that the formulation of S&T policies in the countries identified above with relatively lower levels of accumulated expenditure in R&D should keep on being targeted particularly to foster advanced education of human resources, by encouraging the qualification of human capital. This is because those countries have evolved considerably in terms of the number of researchers and the education level of their young people in recent decades, but still have some way to go in terms of the qualification of their workforce, mostly in a context of increasing competition for qualified human resources at an international level. For example, the unprecedented increase in the level of emigration from southern to northern Europe since 2010 (Figure 4) reveals unsustainable migratory paths in Europe that are affecting the performance of Europe as whole, with short term implications that are augmenting to European divide identified above in this paper. The case of Spain should also be highlighted, as Figure 10 illustrates, namely in terms of the low level of aggregate investment in R&D compared to other larger EU countries, particularly Germany, France and England.

At this stage it is important to mention Goldin and Katz (2008) regarding the role of education in economic growth and the direct relationship between the qualification levels of nations and their aggregate growth rate (see also, OECD, 2008). Recently, the 2006 Nobel Prize-winner in Economic Sciences, Edmund Phelps (2013), also revisited this debate and shown that prosperity growth is associated with values such as the wish to create, explore, meet challenges, and is not fuelled by some secluded visionaries (such as Henry Ford or Steve Jobs), but by millions of qualified people thinking and developing new products and processes, as well as systematically putting improvements in place for those that already exist. Phelps (2013) coined this process as 'mass flourishing'.

It should also be made clear that is not possible to conclude from our analysis that economic growth is a simple matter of investing in education or in S&T. Nonetheless, it is also clear that investing significantly in education over time leads to greater levels of qualification of the workforce and productivity, helping economic growth and improving the quality of life. Goldin and Katz (2008) has shown that the benefits of economic growth may be distributed unevenly and an average pattern of high quality of life may not lead to improvements for all. The implications of these observations for southern and eastern European nations are relevant, especially to consider the challenge to promote equity in access, social mobility and the capacity of provision of a mass and diversified tertiary education system, for which the effort in S&T is a decisive factor (e.g., Heitor and Horta, 2014).

4. Discussion: putting the development of S&T public policies into perspective in Europe

How can the scientific community contribute to make European peripheries successfully meet the challenges of the coming decades, both in terms of economic, social and cultural development, and their international affirmation?

This question has driven most of the analysis included this paper because a polarised debate has emerged in many of those European regions and countries between an utilitarian perspective of S&T – which enhances the economic relevance of S&T, and a cultural perspective – which stresses the values of independence of S&T in light of the "market" and its critical value before the construction of a national identity. We believe that this polarisation of the debate is sterile and that the analysis must focus on the institutional development of the local learning capacities towards socioeconomic growth by reconciling the merits of the two positions. Indeed, southern and eastern European nations should seize out this great opportunity and, above all, this changing backdrop, to address the developments of S&T over last decades, in particular by "indwelling" forms of scientific culture and help managing emerging risks.

In other words, our hypothesis is associated to the concept of "indwelling" firstly introduced by Polanyi (1966) and recently explored by Brown and Thomas (2011) in the context of the "information society". It requires a better understanding of learning societies and policy formulation issues through complex processes of knowing, playing and making (Conceição et al, 2003). Also, on the line of Latour's (1988) principle of "science and technology in action", our analysis suggest the need to better engaging scientific structures with the civil society, in order to position future experiments towards collaborative policy making and science governance through dialogue. This may include the involvement of scientific communities in 'hybrid forums' (Callon, et all, 2009), where scientists, policy makers and lay people meet to agree the purpose and appliance of scientific knowledge in decisions where uncertainty is at stake.

It has become commonplace to mention human capital as an essential condition for knowledge creation and dissemination, in a way that any effort toward greater human capital is extremely important for the social and economic development of any part of the world. In itself, this objective calls for policies to expand the social base toward scientific and technological development and the effective appropriation of scientific and technological culture (Majewski, 2013). This obviously requires opening access to higher education through several mechanisms that take into account non-linear people's experiences and life trajectories (Saar et al., 2014).

A simple estimate of students, aged between 20 and 24, who are currently attending higher education, in addition to those that already hold an advanced academic degree, and keeping the current higher education completion rates, makes us assume that all

European regions will achieve 30 % of graduates aged between 30–34 by 2020 (Heitor et al. 2014). Consequently, in order to meet the European Strategy 2020 goals, which entails achieving 40 % of graduates in that population group by 2020, it is necessary that many more thousand of students aged between 20 and 24 all over Europe conclude their graduate studies, beyond the current graduation levels.

The analysis still shows that the success of opening higher education within the framework that emerges at international level, in which innovation must be considered together with competence building and advanced education, calls for complex interactions between formal and informal qualifications (Helpman, 2004). This requires continuation of a major effort at a wide European level to broadening the social base of knowledge-based activities and strengthening the "top" of the knowledge production system.

If we try to develop further the implications of this argument and the terms which must drive the formulation of national S&T policies across Europe, it is obvious that three vital issues must be addressed: a) scale, especially when it comes to the undeniable need to go on increasing public efforts in S&T; b) diversification, namely regarding the need to perceive the difference between instruments and the role of public and private funding; and c) time, regarding the need to understand a continued effort in S&T.

The following paragraphs draw on data and facts shown above in order to better understand the development of public Science and Technology policies across Europe and put their future development in perspective.

4.1 The basic assumption: linking public investment in science and technology to the systematic reinforcement of human capital

Within a framework of high volatility of a fast-changing society and economy – as it always has been – and at a time where there are segments of society that start to show indicators that most closely resemble the socio-economic features of developed countries, one should conclude (perhaps counter-intuitively) that the system must go on expanding and diversifying in order to meet the quantitative and qualitative needs of the future. The analysis must consider the need to cover an increasing diverse population, the demands of society and of volatile and highly uncertain markets.

In light of the foregoing, the basic assumption considered in this paper for the design of science policies is based on the need to systematically reinforce human capital. In fact, science, its impact and particularly innovation, which nowadays gives us so much cause for concern, result from a cumulative process that has gained roots over collective and mostly uncertain learning processes (Conceição et al, 2003), involving above all an extensive division of labour (Mazzucato, 2013). This implies massifying the qualification of the workforce within a broad range of economic sectors.

wIt is important to clarify the potential for growth of human resources in science and technology. Despite the rapid growth of human resources in S&T over the last 30 years, there is still a high growth potential and, above all, the need to further develop this growth process. For example, human resources employed in science and technology occupations (i.e., "HRSTO") in Portugal and many other European peripheries account for less than a quarter of the workforce in the age group 25–64, whereas, in 2012, this share was around 40 % for the EU-27 average and more than 50 % in Holland, Finland or Denmark, as well as in Europe's most industrialized areas.

4.2 Understanding the impact of S&T policies in economy depends on its level of diversification and internationalization

It is natural and commendable that the formulation of science policies takes account of the economy and, above all, of opportunities for economic appropriation of knowledge. This has been perhaps the argument mostly used in many European countries to reverse policies and/or reduce investment in S&T in recent years (e.g., Mazzucato, 2013).

It is important, however, to note that, despite the current framework of a growing financial vulnerability of many European regions, the accumulation of investment in S&T over the last 30 years has allowed to offset the technological balance and increase exports. It was in this context that the evolution of business expenditure in R&D in Portugal, Spain, Czech Republic and many other countries reflects increasing private sector efforts in valuing scientific development and technological capacity, namely in terms of their innovation potential, access to emerging markets and development of exports.

To help clarifying this discussion, Figure 11 depicts the evolution of total exports for the past 20 years and the accumulation of the gross expenditure in R&D over that period in a sample of small, medium-sized and large European countries. It suggests that R&D investment efforts have been particularly critical to help the most industrialized countries fostering their exports. This is certainly the case of The Netherlands and Germany, as well as UK and France, with the notable figure of Germany to increased its level of exports by four times after 30 years of consecutive investment in R&D. The related correlation of R&D and the access to external markets in Czech Republic and Hungary is also worth noting, as well as in Portugal, although at a lower level. Nevertheless, the analysis clearly shows that these investment efforts still remain relatively low in many European peripheries compared to other small and medium-sized countries. For example, for an investment effort in R&D similar to that of Portugal, the Czech Republic more than doubled its share of exports.

Figure 12 helps clarify the reason why Germany and The Netherlands are the only European countries where the impact of R&D in exports is especially visible, because they are the only countries with a highly diversified economic structure in recent decades. The figure quantifies the level of economic structure diversification through the inverse of the Herfindahl-Hirschman Index (HHI) for economic structure (considering industrial output, or manufacturing, only; see, for example, Waterson, 1984), which is defined as the inverse of the sum of the square of the market share of the various industrial sectors operating in the economy. It therefore allows for analysing the relative levels of concentration/diversification of industrial activity, showing that the impact of R&D activities accumulated over the years is mostly contingent upon the structure of the economies.

In other words, the analysis suggests that only those European nations that have increased the investment in S&T and managed, at the same time, to diversify their economic structure have fully guarantee the necessary *absorptive capacity* to foster the impact of S&T in economic development (see, for example, Cohen and Levinthal, 1990; Freel, 2005; and Vinding, 2004). The implications for southern and eastern European countries are notorious and call for the need to combine an increase in the budget allocated to investment in R&D with measures oriented towards technological diversification and intensity of the industrial base.

Figure 11 – Total exports versus R&D accumulated expenditure per capita (millions of U.S. Dollars 2005 constant prices and PPP);

Source: OECD.

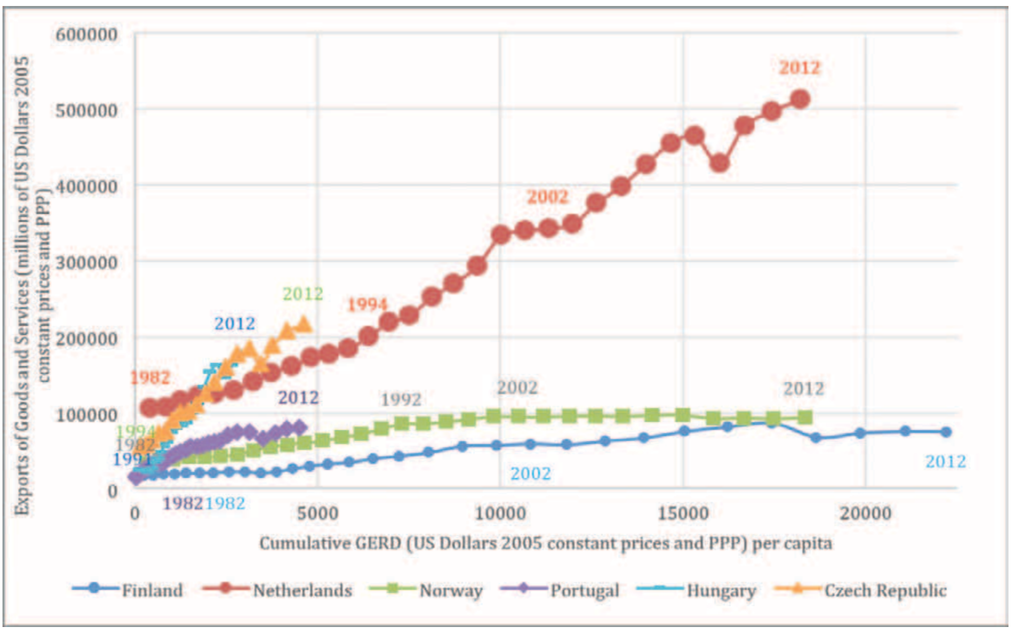

Figure 11a: Sample of small and medium EU countries.

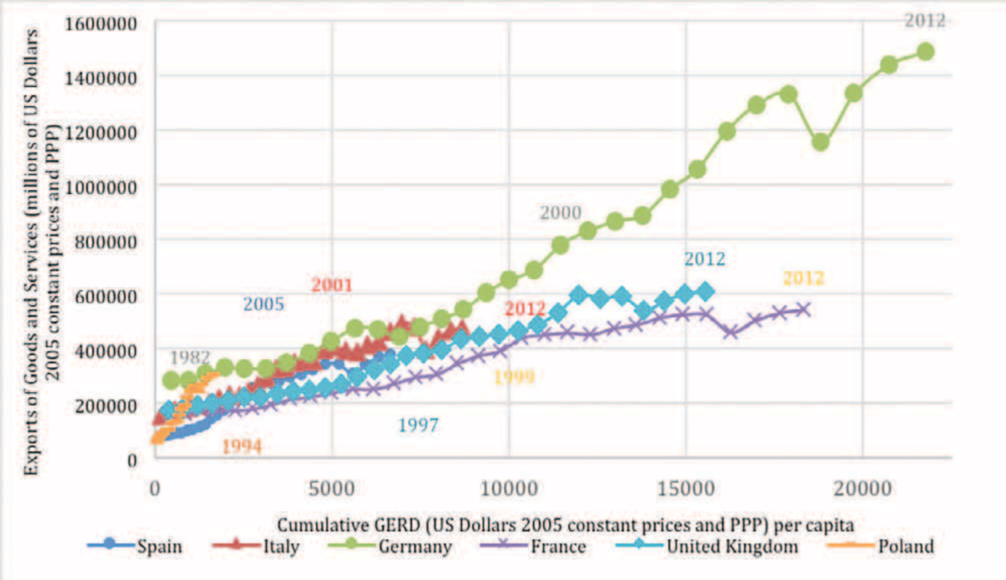

Figure 11b: Sample of large EU countries

Figure 12: Levels of diversification of economic structure: 1980–2010, as quantified by the Inverse Hirshman-Herfindahl Index for the economic structure (only manufacturing);
Source: OECD.

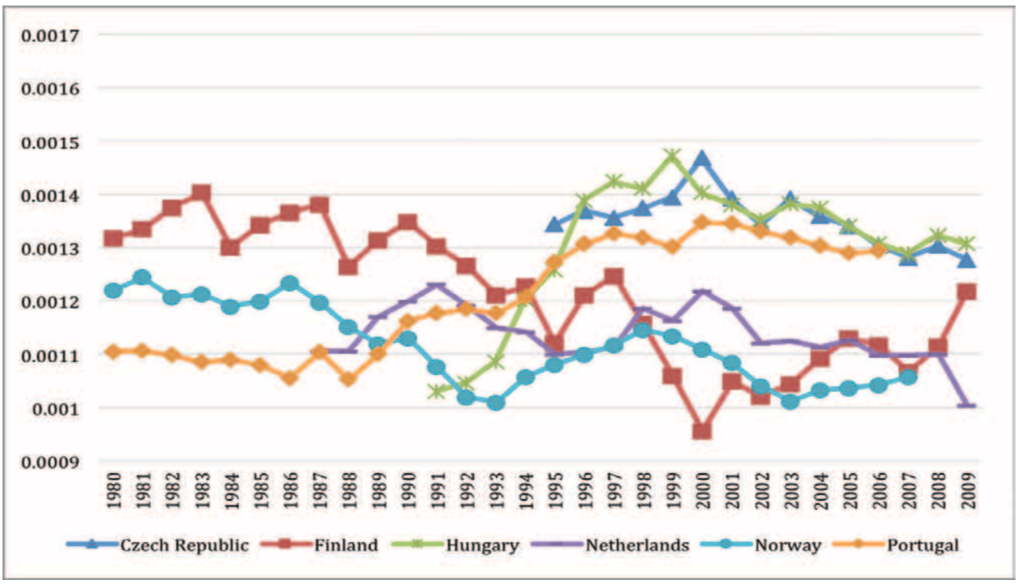

Figure 12a: Sample of small and medium EU countries

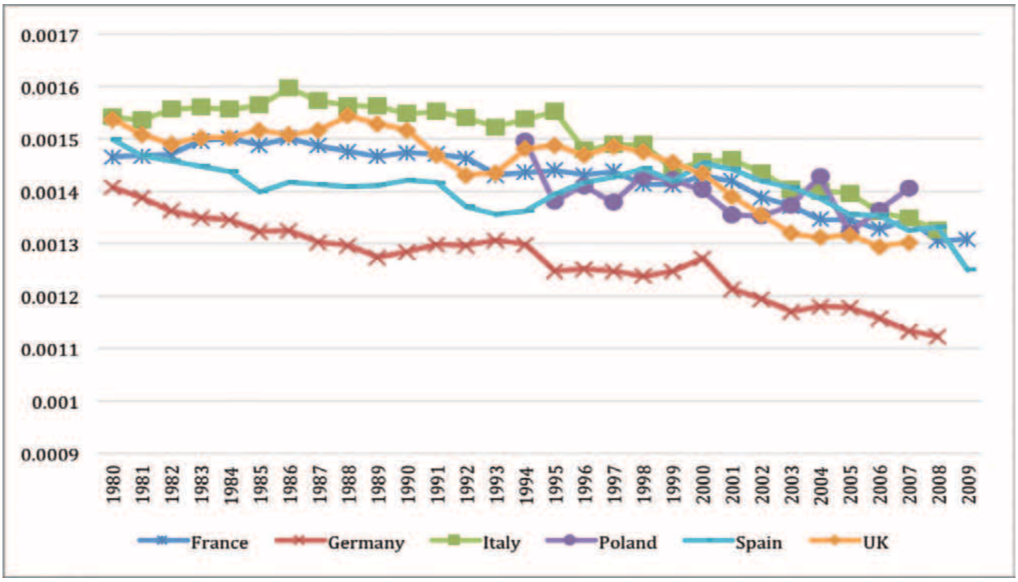

Figure 12b: Sample of large EU countries.

It should also be noted that the concepts of economic diversification and the related development of a sustainable industrial basis, in addition to being distinctive features of the most developed economies, are also associated with the development processes of the countries that have become direct competitors of Western economies in recent decades, such as South Korea (Amesden, 2001) or Taiwan (Berger, 2005). Diversification, in particular, seems to allow for economic growth of countries and regions, mostly because of the increase in consumption. It is also important to the extent that the weight and therefore the dependence on economy of each industrial sector have lost ground. Because almost all knowledge-intensive exports are associated with high-tech manufacturing industries, investment in those industries should also allow for mitigating the risk of regional crises, in that it becomes possible to look for potential markets in other regions. By doing so, diversification is associated with the creation of socioeconomic resilience, i.e. the ability of the socioeconomic fabric, and companies in particular, to promote themselves and recuperate from financial shocks, such as recessions or crises. Nevertheless, the processes related to industrial diversification and specialization, which are linked to competence broadening and development, respectively, are extremely complex and mostly associated with knowledge and technology learning and incorporation processes in people and organizations (Sheffi, 2007).

Against this background, competitiveness in most industrial sectors hinges on the capacity of getting access to and using knowledge developed in a wide and diversified range of institutions that constitute distributed knowledge bases, requiring "learning infrastructure" that facilitate interface activities between industry and those bases (Romer, 1994).

Job creation and quantification is a key issue of the local socioeconomic impact of industrialization processes and, consequently, in the context of the previous analysis, sustainable development of technological and industrial bases calls for building distinctive competences. This process must be based on qualified human resources and investment in research and development, thereby contributing to continuously develop those competences, gain experience and, therefore, may help build up competitive advantages (Cohen and Levinthal, 1990).

The analysis suggests the need to continuously assess the potential for growth of technological intensity in European peripheries, namely in terms of the participation of the private sector in efforts to increase local technological intensity. On the other hand, it also suggests that large companies need to increase significantly their investment in R&D in order to optimize scientific employment routines in the private sector, along with the specialisation of their skills. In particular, public policies and regulatory framework should be oriented to stimulate consortia of market leading companies oriented towards increasing national exports as a way to allow companies to enter emerging markets more easily.

It should also be noted that R&D outcomes tend to be characterized by strong spill-over effects, i.e., the benefits for those who carry out R&D go well beyond the investing entity. From the point of view of companies, this leads to an underinvestment in R&D, because there is no full appropriation of benefits of that investment (Conceição et al., 2004).

The conclusion is that public policies geared for increasing private expenditure in R&D should embrace increasing public expenditure, which is counter-intuitive in light of a "linear" interpretation of the innovation generating mechanisms. Nevertheless, that is a right conclusion considering the characteristics of R&D in its complex relationship with economy, technological innovation and scientific development (Romer, 1994; Lundvall and Johnson, 1994). It is well known that, when tracking the trajectory of the countries that today most invest in private funds in R&D, it can been seen that this outbreak has been historically preceded by high and sustained public investments in R&D (e.g., Conceição et al., 2004).

4.3 The role of the State

Although the functions that are socially allocated to scientific institutions start being shared by a wide spectrum of institutions, Public States are now faced with demands for an increased presence of its capacity to promote knowledge creation and dissemination (Mazzucato, 2013; Stilgoe, 2013). In fact, we could also argue on the exclusive role that Public States should take on to ensure system diversification, inter-institutional mobility, initial cooperation with companies, as well as institutional integrity and internationalization. However, one must remember that the role of the State as guarantor of institutional diversity and integrity must be implemented through funding and assessment mechanisms.

The indicators used in this study show that, at the threshold of the 21st Century, the average funding rate per researcher in most southern and eastern European countries continues to be a third of that in the most industrialized European countries, and a researcher in higher education in Europe has approximately half the funding of a researcher in the US. Comparatively, the level of GDP per capita in most southern European regions (e.g., Portugal and Greece) is about 75 % of the average share for Europe which shows an effective deficit of R&D funding in those regions, particularly in cumulative terms.

The importance of this discussion lies in the fact that several models of economic growth have allowed for explaining the increase in per capita income in developed countries depending on the degree of knowledge accumulation, which has provided grounds for considering S&T evolution as endogenous to economic and social development (Romer, 2004; Conceição and Heitor, 2002). Within this framework, there has been in recent literature the need for considering institutions and policies in order to explain cross-country differences in terms of knowledge and per capita income generation.

Against this background, the evolution and modernization of European science and technology, as a whole, cannot be devised in a conceptual void, not even ignoring the complex arrangement of values involved, in addition to the facts that characterize science output and dissemination. Among other aspects, it is appropriate to point out the seminal work of Robert Merton, a prominent sociologist (deceased in 2003) who, in the 1950s, showed us the so-called "serendipity" nature of knowledge production and diffusion (Merton and Barber, 2004). From the stories of Archimedes to the accidents that were on the basis of the discovery of penicillin by Fleming, and the development of new materials such as Teflon, accidental happenings in science, but mostly in innovation, are today well-known and documented (e.g., Johnson, 2014).

It must be made very clear that we do not mention any lack of scientific values, but a well clear priority to increase the dimension of the science and technology system, as well the average funding per researcher. Against this background, Paul Romer (2000), a well-known US economist, is well worth mentioning. Among other aspects, he showed that the role of public policies designed for preparing scientists and graduates is particularly critical for long-term economic growth, and these policies have been responsible for the fast growth of the number of engineers and scientists in the US in the post-war period.

Nevertheless, knowledge creation and dissemination acceleration intensity requires a more in-depth characterization, because the critical aspect is associated with a dynamic perspective, as analysed by Conceição et al. (2003) in a European context. According to these authors, there is not only knowledge that becomes really important, but also knowledge that become less important. There is both knowledge creation and destruction, which forces us to understand knowledge creation and dissemination processes. In short, sustainability growth of the economy and the learning society in which we live, namely at global level, is a task that goes beyond traditional challenges. Changes in workforce composition, along with the ever-increasing internationalization of economy, the constant advances in technology and dissemination of new innovative labour organization models, call for a substantial investment in human capital so that the requirements in terms of skills and qualifications of future employment are met.

In this respect, we cannot expect that private initiative, per se, increases R&D activity and solve the issues of employment and wealth in Southern and Eastern Europe. The need that emerges from diversifying mechanisms for funding innovation and developing S&T, namely its link to companies and to the productive fabric, requires public policies that promote scientific employment in association with areas of large public and private investments. Public policies are also critical to mobilize public resources in science and technology, allowing qualified people and knowledge to be available to conduct R&D in companies.

Summary

This paper shows that public policy formulation in Europe after a decade hit by recession and economic and budgetary problems must take into account countercyclical measures, while focusing on advanced education of human resources and strengthening S&T in all branches of knowledge. The continuous qualification of the workforce at large is a persistent challenge that requires broadening the social base for advanced education, as well as for internationalization.

Science, together with its dissemination and social and economic appropriation need time. Furthering the debate on the role of public policies in economic competitiveness, giving priority to knowledge and technological change processes and innovation, in the course of a hard economic and budgetary adjustment programme at international level and, mostly in southern Europe, is undoubtedly a huge challenge and requires the mobilization of all.
Why is it not trivial that understanding that investment and research in universities creates jobs and exports and is indispensable for long run growth in modern economies and societies?

The analysis of this issue is not new and has been recurrent worldwide. New York Times columnist and multiple Pulitzer prizewinner Thomas Friedman, who considers that “the world is flat”, argued on the danger of “commonplace”. He said, “Countries that don’t plan for the future tend not to do well there”. Furthering Friedman’s argument,

it is the investment in our collective institutions and opportunities, mostly through research in our universities, the best way to cope with the growing inequality worldwide, where some entrepreneurs may become millionaires overnight, whereas universities and research centres have been steadily been deprived of their resources.

Southern and eastern European people, among many others, start to understand today what sustained investment in university research represents and what role higher education and scientific institutions play in the progressive stimulus for innovative companies and global markets. In recent years, it has been very important to place many European countries and regions on track with EU average investment levels in R&D, but this remains insufficient. In addition, the accumulation of that investment is still very low, compared to any industrially developed region with access to emerging markets.

It is known that, in order for R&D expenditure to turn into technological innovation and economic growth, it is important to know either the type of funding that sustains that additional expenditure or who does the research. It is research done in a business setting that most directly relates to the emergence of new products likely to be exported to global markets and that most contributes to productivity growth and boost competitiveness. But the main issue is that we know on a global scale that the best strategy to increase spending executed and funded by companies consists in a strong and sustained growth of the public share of public funding for R&D, namely in universities. This statement is apparently counterintuitive. Broadly speaking, public spending drives down (or crowds out) private spending. If the State builds a road next to the door of a new factory, the company that invested in the factory will not build the road: therefore, there is a crowding-out effect.

R&D expenditure does not produce a crowding-out effect, such as when the State builds a road next to a new factory and the firm that invested in the factory does not in fact build the factory. There is no crowding-out effect of private expenditure when it refers to university-based scientific research. Research done in universities and scientific institutions translates not only into new outcomes in science and prepares academic staff and new doctorates, but also experts and skilled labor force. This is one of the most important mechanisms that contribute to cater for the needs of companies and the labour market in terms of those experts, researchers and technicians. Academic-based research has increasingly given way to new high-tech companies, which create jobs and generate exports. University-based research, carried through with companies generates technology transfer that pushes companies forward, develop new products, new markets and again exports.

In short, the increase in R&D expenditure carried out in universities and firm is not inevitable, but a choice. European citizens at large and their governments must make this choice, and it is important that they are aware that if we do not continue to grow in those areas, it will be difficult to encourage technological innovation and economic competitiveness. In order to attain these objectives, it is paramount to mobilize and employ more PhD graduates throughout entire Europe, foster research in universities, strengthen the relationship between universities and the business sector, and guarantee scientific and technological relationships with the leading institutions worldwide. And this can be only achieved if we simultaneously stimulate demand and supply of the ability of carrying out R&D.

The current level of southern and eastern European economic and technological development requires a major and sustained effort of R&D public financing. This will contribute not only to graduate new PhD students but also, directly and indirectly, to foster demand. This has been the way regions and countries with high levels of R&D and a large percentage of R&D have made in companies and funded by companies have followed. The faster and greater involvement Europe at large addresses this challenge the quicker it will be kept up with.

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Unlocking Research Potentials and Regional Implications of Development

Massimo Monteleone[1*], *Maurizio Prosperi*[1], *Emmanuel Koukios*[1,2]

[1] STAR*Integrated Research Unit, Department of Agriculture, Food and Environment, University of Foggia, Italy (star.7fp@gmail.com)

[2] Bioresource Technology Unit, School of Chemical Engineering, National Technical University of Athens, Greece (koukios@chemeng.ntua.gr)

* Corresponding author (massimo.monteleone@unifg.it)

Abstract

The overall plan and the strategies carried out in the framework of the EU project STAR*AgroEnergy (FP7-REGPOT-2011) are presented as a reference case study on "capacity building".

STAR was intended to significantly improve the research capacity of the University of Foggia and its ability to act as a "hub" for the promotion of bioenergy and bioeconomy, which implied strengthening the research power, bolstering the links with stakeholders and fostering capacity building activities.

Three parallel pathways of investment in research capitals were applied: *a)* improving the research activities through an interdisciplinary approach ("bonding" by research integration inside university); *b)* consolidating a critical mass of researchers ("bridging" by recruitment outside university); *c)* expanding the research network through large and qualified scientific and non-scientific collaborations ("linking" through two-way secondment collaborations and institutional partnerships).

One major strength is the high level of integration achieved between the two major drivers of scientific and technological innovation: "research community" and "local stakeholders". On this view, research and technological development is conceived as an innovation opportunity for the region, supporting the regional economic trends and in-tune with its social needs.

The STAR research Unit aims at an integrated approach to renewable energy generation derived from agriculture and agro-food industries and to a knowledge based bio-economy, according to sustainability criteria. The target is to build up a methodology to reconcile bio-based production with nature and landscape conservation, the maintenance of ecological resources and the protection of cultural heritage of the most relevant rural areas of Southern Europe, working out models of viable, dispersed bioenergy generation and biorefinering together with proximal energy consumption.

Key words

capacity building, development, research capacity, bioeconomy, bioenergy & biomaterials, smart specialization, key enabling technologies, social capital, triple helix model.

1. Introduction

1.1 Capacity building, research capacity and development

The 2014 edition of the International Conference on Technology Policy and Innovation (ICTPI) was devoted to opportunities, challenges, and policies related to capacity building in emerging technology regions (ICTPI, 2014). The concept of *capacity building* (CB) finds its scope to support the practical needs of development with respect to countries, communities and organizations. The United Nations Development Programme (UNDP) was one of the first organizations to deal with CB and provided a useful starting definition. CB is defined as a "long-term, continual process of development that involves all stakeholders, including ministries, local authorities, non-governmental organizations, professionals, community members, academics and more" (UNDP, 1997; 1998). The goal of CB is "to tackle problems related to methods and tools of development, while considering potentialities, limits and requirements associated to the concerned entity (country, community or organization)". According to the same UNPD definition, CB is the process by which individuals, groups, organizations, institutions and / or societies increase their ability "to perform core functions, solve problems, define and achieve objectives effectively, efficiently and sustainably". The scope is to understand and deal with their development needs in a broad context and under a contrasting set of circumstances. The UNDP also outlines that CB takes place on a three-level hierarchy: individual, institutional and societal. This three dimensional approach to increase and reinforce capacity will be detailed here in after.

CB should be considered closely linked to the concept of a "learning" organization that constantly changes and adaptively experiments by using feedback of its results to change its form and processes in ways that make it more successful (van Geene, 2003). CB can be seen as a process (rather than a product) inducing a multi-level change in individuals, groups, organizations and systems. Ideally, CB seeks to strengthen the self-adaptive capabilities of people and organizations, in order that they can respond to a changing environment on a dynamic basis. CB is a planning approach that turns ideas into action; a continuous process of adjusting people's attitudes, values and organizational practices while building up appropriate knowledge and skills among various stakeholders in a partnership.

Improving the capability to do and use research is of the topmost importance and should be thought as a relevant dimension of CB. *Research capacity* (RC), therefore, is a fundamental pillar of the development process characterizing emerging technology regions. RC could be defined as the abilities of individuals, organizations and systems to undertake and disseminate high quality research efficiently and effectively. Enhancing RC is a CB process itself. This means improving researchers' skills, as well as their access to research information and resources; supporting researchers in playing a more regular and effective role in policy-making; paying special attention to skills gaps (when present) in science and technology (Thomas and Wilson, 2010). Strengthening RC is one of the most powerful, cost-effective, and sustainable means of advancing knowledge, technology, innovation and development (CHRD, 1990). Building RC is similar to building other kinds of organizational capacity (White, 2002). In management terms, building such a capacity reflects a commitment to "quality improvement" and characterizes what we have defined already a "learning" organization (Senge, 1990). RC, therefore, is aimed primarily at research managers and at any team leaders and researchers who need to familiarize themselves with the concepts and practices of capacity building and organizational development (Thomas and Wilson, 2010). Therefore, it is directly relevant to those running research consortia involving a range of partners. However, its principles are relevant to a much wider audience since society at large should be involved in building capacity, from the ground up, within each given context.

To fulfill this introductory section and provide elements able to define properly the key concepts on which this paper is focused, it remains to clarify the term "development". Since CB is aimed to promote development, is there a common understanding on what "development" really means? What, it is supposed to achieve and what should be its preeminent qualifications or attributes? There is no doubt that countries with similar average incomes can differ substantially when people's *quality of life* is accounted for; access to education and health care, life expectancy, employment opportunities, democratic participation, availability of clean air and safe drinking water, are all possible indicators and many others could be selected to create a panel. It is true that *economic growth* can also enhance its potential for reducing poverty and solving other social problems. However, history offers a number of examples where economic growth was not followed by similar progress in human development. Instead, growth was achieved at the cost of greater inequality, higher unemployment, weakened democracy, loss of cultural identity, or overconsumption of natural resources needed by future generations (Soubbotina, 2004). On this respect, "sustainable development" is a term widely used by politicians and civil society; a huge *corpus* of definitions and interpretations is available in the literature and is not the scope of this paper to address this complex issue. "Sustainable" development could probably be otherwise called "equitable and balanced", meaning that, in order for development to continue indefinitely, it should balance the interests of different groups of people, within the same generation and among generations, and do so simultaneously in three major interrelated areas: economic, social, and environmental, respectively.

1.2 The EU policy

Europe 2020 (EU-COM, 2010) is a 10-year frame strategy proposed by the European Commission for advancement of the economy in the European Union. It follows the *Lisbon strategy* for the previous period 2000–2010 and it aims at "smart, sustainable, inclusive growth". On this respect, Europe 2020 puts forward three mutually reinforcing priorities:

- Smart growth: developing an economy based on knowledge and innovation.
- Sustainable growth: promoting a more resource efficient, greener and more competitive economy.
- Inclusive growth: fostering a high-employment economy delivering social and territorial cohesion.

Considering the EU research policy, we have just entered in the new programming period 2014–2020 and the *Horizon 2020* Programme is now running as the successor of the *Seventh Framework Programme* (*FP7*). In the previous programming period, a specific action to promote R&D was launched and carried on in the years 2007–2013. The name of this action was "Research Potential" (REGPOT) and it was intended to strengthen research potential as well as to forge synergies between regional development and innovation strategies. Considering the 2007–2013 period, the FP7 Research Potential programme supported 169 projects with € 340 million (EU, 2014). Under *Horizon 2020* the "Research Potential" programme have been transferred to the EU's "Cohesion" policy and the new EU State members are now reshaping the scene inside the "enlarged" Union.

1.3 Scope of this work

All this considered, and benefitting from the closed FP7 programming period, this could be the appropriate moment to look back at the previous programme, to identify some key findings, and to draw lessons for the future.

The peculiar feature of this paper is to address the analysis from a specific and real case, namely a three-year European REGPOT project, and to carry out an investigation according to a "bottom-up" approach. This work is not intended to proceed into a comprehensive evaluation of the EU policy on "Research potential"; no results or statistics about funding and achievements at large will be presented here. On the contrary, the true aim of this paper is a sort of "narrative" about the direct experience a research team that benefitted of a REGPOT funding had to face. It is considered worthwhile to reconstruct, since the beginning, the vision, the applied strategy and the progress plan, the awareness developed, the changing in mindset and the attitude with respect to the internal and external environment of the team, in order to gain significant improvement in research, reinforce research capacity and achieve a better ERA integration. It could be considered a successful story, although still a long path should be followed.

Emphasis is also addressed on how (what methodologies and actions) such initiatives have established a virtuous combination with regional development needs, so grafting into the regional cohesion policy.

The project this paper will discuss about is named STAR*AgroEnergy (Coordination and Support Action – FP7-REGPOT-2011–1). The acronym STAR stands for *Scientific*

& Technological Advancement in Research on Agro-Energy – an Integrated Approach to Renewable Energy Generation According to Sustainability Criteria.

The STAR project could be considered as a "case study" in research capacity building. What was learned from this experience? What are the successes and, conversely, the failures that are worth to be mentioned for future applications? A wide spectrum of different activities have resulted from this project. Each activity should be considered part of a comprehensive strategy to boost research, reinforce human resources, strengthen management as well as improve experimental and technical equipment.

2. EU strategy to unlock the research potential

The objective of the EU "Research Potential" programme is to promote the full research potential by unlocking and developing existing or emerging excellence in the EU's convergence (and outermost) regions as well as helping to strengthen the potential of their researchers to successfully participate in research activities at EU level. Research and innovation are considered indeed key drivers of competitiveness, job creation, sustainable growth and social progress.

Many research actors located in the EU convergence regions have difficulties to become active players in in the European Research Area (ERA) and are facing problems of brain drain, lack of infrastructure and of appropriate access to finance as well as low innovation performance. There is a clear need to fully integrate them in the ERA.

A well-defined "action plan" is to be implemented progressively during the realization of a "Research Potential" project applying the following coherent measures:

- *Exchange of know-how* and experience through trans-national two-way secondments of research permanent staff between the applicant and experienced "partnering organisations". Additionally, partners from the applicant's country can be involved and, when appropriate, stakeholders like enterprises, SMEs, etc.
- *Recruitment of experienced researchers*. In this context, the return of nationals having left the country is encouraged. Experienced engineers, scientists or technicians for running the newly acquired equipment are also eligible.
- *Upgrading, development or acquisition of research equipment*. This measure should not account for more than 30 % of the total project budget.
- *Organization of workshops and conferences* to promote knowledge exchanges at EU and international level targeting the research excellence reputation and the visibility of the research team. Active participation of research staff at international conferences, for knowledge sharing, network building and to expose them to a more international environment are also relevant.

- *Dissemination and promotional activities* for knowledge sharing, networking and for better visibility at national and European level.
- *Elaboration of a strategic Intellectual Property development plan* for IP management and protection and innovation capacity building. The plan will provide a framework for improvement of IP and protection of know-how.

In order to ensure a long-term sustainability of the research entity, synergies between the measures proposed in the "action plan" and measures supported through the "cohesion policy" programmes should be carried out as a clearly achieved added value. The expected impacts consequent to the realization of these activities should concern:

- Unlocking and developing the research capacity for an effective contribution to regional economic and social development thanks to a well developed innovation dimension
- Improving human resources and research management.
- Exploiting innovation potential, particularly in the less advanced regions that are remotely situated from the European core of research and industrial development.
- Promoting a strategy of inclusiveness to benefit both research community and industry.
- Fostering a better integration into the ERA through a long-lasting partnership with excellent research groups and relevant stakeholders. Stimulate a stronger participation to EU research calls.
- Upgrading RTD capacity and capability (human potential: number of new researchers and training of research staff; material potential: modern scientific equipment) as well as the quality of research carried out by the research entities.

3. Close to the turning point: a new paradigm begins

Every action starts with a vision, is guided by a concept, is oriented by a mission statement. If reference to research is not in the mission statement, developing a relevant research capacity is made more difficult. The STAR integrated research Unit developed a clear understanding of the vision underlying the selected research issues and about the motivations that led the team addressing significant research topics related to a new approach to science, technology and industrial innovation. These issues, far from being merely technical, also have a clear social inspiration and suggest a model of society in tune with nature, and founded on true participative principles.

The world energy economy is currently undergoing a critical period of transformation in technology, governance, social and economic values of energy. A new economics of energy is heralded by national and international negotiations and the assumption that economic growth can be supported largely by fossil fuels is fading rapidly.

The current international situation is characterized by a very acute and serious phase. The environmental crisis is rising dramatically, leading our planet towards an imminent depletion of many natural resources (oil, water, soil fertility, etc.). The importance of fossil fuels in the current productive systems (as source of energy and raw material), in domestic use (heating and electricity consumption), in agriculture (fertilizers, pesticides, fuels), in industry (plastics) and transportation, together with the difficulty to rapidly replace these fossils with renewables of equal power and versatility, make this kind of constriction very dramatic.

To face such challenges and exploit new opportunities, it is imperative to develop novel, renewable sources of energy and raw materials, to be selected in relation to social, economic and environmental conditions of the specific regions.

Recently "bio-economy" has been gaining more and more momentum. The term refers to a broad range of activities in different productive sectors whose common goal is the sustainable use of renewable biological resources for the obtainment of a variety of end products (such as food, feed, biofuels, bioenergy and fine-chemicals). Bioenergy (i.e. the utilization of biomass for the production of transport fuel, power generation, heating & cooling) is a key element of a bio-based economy. Complementary to bioenergy, the *biorefinery* concept is now frequently used to address new bio-based value chains in the chemical industry (the so called "platform compounds" molecules).

An ecological conversion of the productive apparatus and new patterns of resource consumption are unavoidable. The transition from an economy exclusively centred on fossil fuels toward a mix of renewable energy sources, eliminating all forms of waste (properly converted into useful resources) and increasing the energy use efficiency has to be encouraged.

Correspondingly, food security from a healthy agriculture, in ecological equilibrium and preserving biodiversity, is the other side of the same conversion process. A decisive factor could be to convert the traditional mono-purpose agriculture (centred on intensive farming systems aimed to maximize crop production) to multi-functional cropping systems. The latter are based on an ample range of objectives, apart from food production: soil protection and bioremediation, water saving, landscape preservation, valorisation of marginal lands and abandoned agricultural areas, together with bioenergy generation and biomaterials. Biomass feedstock from dedicated energy crops, agricultural residues or agro-industrial waste might be extremely useful to obtain fuels, power and heat, together with added value chemicals and industrial components while, at the same time, reducing CO_2 equivalent emissions, increase soil CO_2 capture, save fossil resources, increase soil fertility and reduce the overall environmental impact of the productive apparatus.

Centred on this general diagnosis, the *vision* the STAR Research Unit has progressively developed is to apply an integrated approach to renewable energy generation derived from agriculture and agro-food industries and to implement technological criteria closely inspired to a knowledge based bio-economy, according to sustainability principles. The target is to build up a methodology to reconcile bio-energy production, as well as several others bio-based end-products obtained from biomass, with nature and landscape conservation and the maintenance of ecological resources, working out models of viable, dispersed bioenergy generation and biorefinering together with proximal energy use. This has to be done avoiding competition with food/feed production. An intelligent decision should be R&D based and experimentally proven.

4. (Anti)methodological approach to strengthen research capacity

A strategic plan (as well as a research agenda), in addition to the "vision" as the first element, incorporates general objectives and specific goals, defines methodologies and approaches, draws up actions and measures, sets a monitoring design, and an evaluation procedures. In turn, a periodic and cyclic revision of goals and objectives should be conceived (White, 2002).
Not deliberately, a sort of "syncretistic" attitude and "eclectic" approach in CB were applied. At the beginning, having no specific methodological awareness, different kind of knowledge, guidelines, and instructions coming from several approaches and disciplines were assembled, hopefully in synergy, and cautiously used. Probably, this could be conceived as a "naïve" behaviour; in fact, it was through "learning by doing" that progressively the research team better focused its targets, consistently improving its standard, visibility and influence. This process of gradual consolidation was initially based on the energy and enthusiasm of a relatively small number of "initiators" (or "pioneers") that had the capacity to transmit this "charge" firstly to the closest colleagues, gradually expanding the range of this positive "contamination" (like an "auto-catalytic" process).

Epistemologically, this kind of empiric approach could be defined, *ex-post*, as "against method" (*sensu* Feyerabend), defending the idea that there are no methodological rules to constrain the process and considering that "rules" generally do not contribute to scientific success. In other words, prescriptive scientific method would limit the activities of researchers, and hence restrict scientific progress. In this view, science would benefit from a (homeopathic) "dose" of theoretical anarchism.

5. The three dimensions of research capacity

As reported already, research capacity can be conceptualized as the combination of three interrelated and integrated levels: the individual, the organizational and the institutional levels.

The *individual level* requires the development of conditions that allow single participants or small groups to build and enhance knowledge and skills; consequently, it involves the development of researchers and of the research team. Not only research training but also how to design and undertake research, how to publish on high impact journals, intercepting research funding, consolidate a critical mass of researchers, are all activities and objectives related to this level.

The *organizational level* is focused in the development of research capacity at Department level, or within Universities and research Institutes. At this level, the focus is mainly on the management of the research system, towards a better quality of research able to better interact with society.

Finally, the last is the *institutional level*. It should support the establishment of a more "interactive" public administration that is responsive and accountable. At this level, we are focusing the "rules of game", that is to say the politically and regulatory context and the long-term strategy. Very pertinent questions at this level are: How are resources allocated? According to what kind of final targets or specific criteria is this allocation performed?

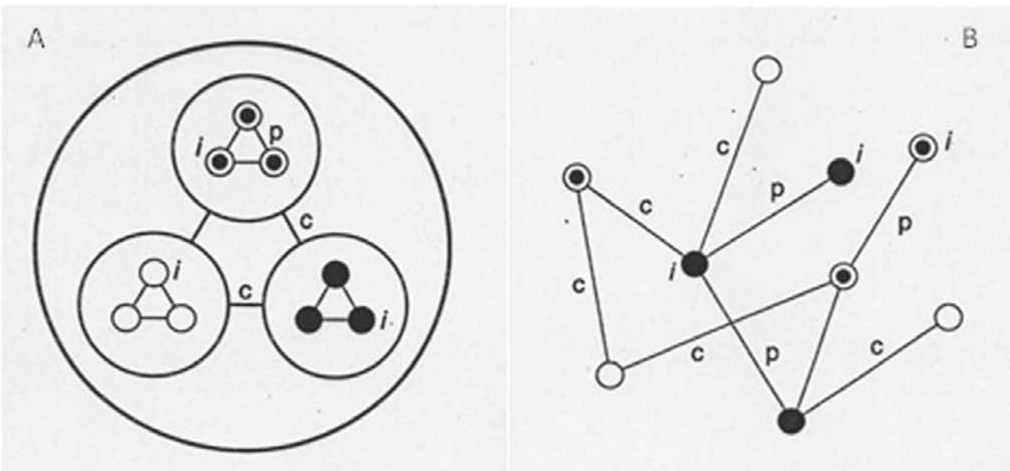

Figure 1: Schematic comparison of the two contrasting model related to the research & innovation system, the "hierarchical" (A) and the "membership" models, respectively.
More details in the text.

These three levels might overlap substantially and there are no sharp or clear boundaries among them. No doubt that we can easily identify these three levels when we focus our attention on the research system. The real question is: How can these three levels interact each other or how they are linked? According to a "hierarchical" concept, only contiguous levels can affect each other (Fig. 1). Differently, according to a "membership" model, links and bridges can be activated among every levels of organization, to affect, influence, modify, and produce adaptations or changes with respect to every other organization levels, no matter the closeness among them (Fig. 1). This latter model is similar (or analogous) to the game tactics of the so-called "total football" (very popular in the 70s of the XX century and originally conceived by the Netherland football team); according to these game tactics there are no fixed roles by players but great adaptability to play different roles according to the prevailing conditions of the match. When considering a Research & Innovation system, a very good analogy is to think at the system as an "ecological pattern", or an "ecosystem mosaic", with several patches or "tesserae", all interconnected. The "fractal" dimensions showed by this pattern means that the same organizational rules are acting or functioning at every hierarchical level and a "self-similarity" is the emerging rule or the ordinating factor. A second analogy (or similarity), when considering a Research & Innovation system is to think at a neural tissue, made of billions of neural cells, connected one another without any kind of hierarchical structure. This refuse of hierarchy is another interesting feature that leads the model we assumed to that conceived by Feyerabend (2010).

6. Soliciting "social capital"

Three parallel and interconnected strategic pathways in unlocking and developing research potentials have been identified and consequently applied. This strategy is based on the concept of "*social capital*", i.e. the expected collective benefits derived from the cooperation between individuals and groups, considering the core idea that "social networks have value". Social capital is a concept that describes the extent and nature of relationships people have with others, with their communities, institutions and systems. Social capital theory distinguishes between 'bonding', 'bridging' and 'linking' forms of social capital (Narayan 1999; Woolcock 1998). As in the previous section, we can see that a similar conceptual triad highlights the milestones along the CB process.

The first path is "*bonding social capital*" and it refers to trust-based, co-operative relations among members (researchers and administrative staff) inside the same organization. This means to gain stronger ties in multidisciplinary collaborations within the team and the research unit in order to get a better organization and innovative approaches, thus reaching a higher research capacity. Improve and qualify management activities also pertains to "bonding", targeting a better organization of the management staff.

The second path is "*bridging social capital*" and it comprises to establish mutual relations between researchers from different European Countries and research Institutions. This kind of connections within a multifarious "research milieu" is specifically related to "mobility" and the aim is to push ahead the research team by means of international collaborations.

Finally, the third path is "*linking social capital*" that comprises relationships among people who are interacting across explicit, formal or institutionalized authority in society. In other terms, this means connections with public and private institutions, organizations, enterprises, in order to generate a proper impact of research.

These three parallel paths are similar to the concentric waves formed when a small stone is thrown into a pond (Fig. 2). While the first ring represents the gain of internal consolidation within the team, the second ring signifies the strengthening of the research activity by recruiting experienced researchers from outside. Parallel to recruitment, another opportunity to improve significantly the CB impact is offered by the two-way secondment (incoming and outgoing researchers and people from the administration). Finally, the third ring denotes the need to link research in our own Institute, Department or University with other European institutional partners and to establish collaborations with stakeholders.

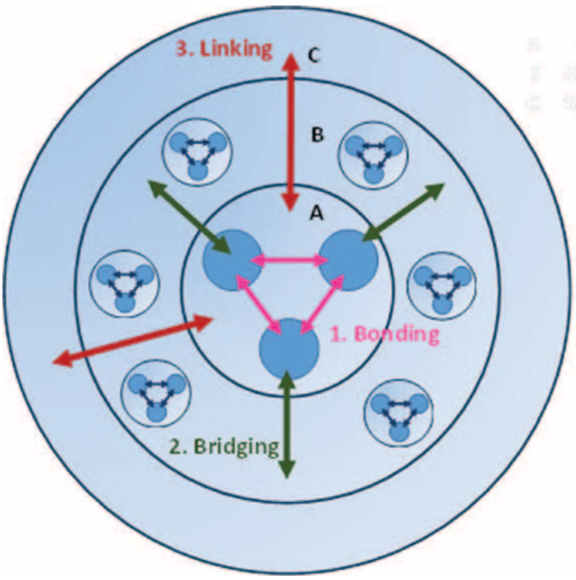

Figure 2: Strategic approach to unlock research capacity based on the concept of "social capital". A) integrated research Unit; B) allied research Institutions; C) society and economic world.

More details in the text.

7. A new and open research mindset

The strategy to unlock research capacity in terms of *social capital* was previously explained. Another feature or trait of this overall strategy should be related to the mental attitude of researchers and research team. It demands *a completely new mindset* in the way to approach research, as well as establish relationships inside and outside the research team. A certain number of empirical guiding principles, gained from experience, were developed within the STAR research Unit. We would like to report just few sentences that do not need to be explained further and that easily describe a new attitude of the research team:

- Be a "seed" of change in your own research community (and in the larger community of your community).
- There are no limits or boundaries but "frontiers" (the frontiers are ideal lines where people is "in front", or "face to face", keen to exchange ideas and proposals).
- "Surfing" is on the crest of the waves. Hang out at the "edges". Nothing happens in calm waters.
- "Growth" is worked from within but "vision" is developed looking outside and far away.
- A strong hierarchy is never relevant, especially in research. Be a protagonist (with no frenzy to be a star).
- Be "connected" and establish a dense and effective collaboration network. Create and expand your co-operation "rhizome".
- "Work as a hub", boost your research capacity by intensifying knowledge exchanges in both directions (from science to society and the opposite).
- Be "tuned" and address your research activities considering the most urgent, needed and felt topics in your research field.
- Approach research "systemically", think globally, recognize the general pattern of every question, go beyond specialization, understand the context and the framework. Be careful to the implication of your work.
- Be "adaptive" and "responsive"; be able to reorient dynamically the development strategy according to external inputs and a changing context.

This set of guidance, considered as a whole, is useful to identify a sort of research "style" or, is also possible to say, our inner "beliefs" and research attitude. The STAR research Unit considers this lines as the "core" trait of the interdisciplinary viewpoint that characterizes our research approach.

8. From inter- to trans-disciplinarity. Still a long journey to travel.

The surplus value gained by an interdisciplinary research unit is the ability to cope with scientific problems according to a system-approach vision, driving attention on interactions and overlapping rather than single or narrow problems.

The boundaries between interdisciplinarity and transdisciplinarity are fuzzy, since a transdisciplinary research is currently distinguished from interdisciplinary research simply based on a higher degree of knowledge integration. We will see, in a while, that a further effect of integration is the "expansion" of the research space and the rise of unexpected questions. According to the US National Academy of Sciences interdisciplinary is a research approach that "integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice" (NAS, 2005).

Research carried out within the boundary of a single academic discipline limits the potential variety of scientific and local knowledge that can contribute to the understanding of the issues at hand and the generation of new knowledge (Miller et al., 2008). A step further is the *multidisciplinary* approach, where several academic disciplines are jointly involved and the exchange of knowledge is a prerequisite to progress in understanding the scientific issues put forward. There are bridges across the disciplinary borders, so that disciplines improve and evolve but just in parallel, without any kind of integration. This integration of knowledge from different backgrounds fails because is not perceived as the added value of a new methodological approach, although researchers are working on a common issue (Tress et al., 2006). Differently, researchers involved in an *interdisciplinary* approach are required to look beyond their own discipline, and work with the other relevant disciplines to find areas of overlap that are likely to yield new understanding and a different quality of knowledge (Bammer, 2005). Therefore, interdisciplinary research incorporates a greater degree of integration with respect to a unified research problem, firstly considering a shared formulation of the research issues and common methods of evaluation, perhaps even the creation of new questions (Eigenbrode et al., 2007). Finally, *transdisciplinarity* connotes a research strategy that crosses many disciplinary boundaries to create a holistic approach. The integration of diverse forms of research is now the shared goal of the knowledge process, specifically planned to reach the unity of knowledge beyond disciplines. This approach generally includes specific methods to relate knowledge with problem-solving. This strategy is particularly useful when the nature of a problem is under dispute, and can help to determine the most relevant problems and research questions involved (Funtowicz, and Ravetz, 1993). When knowledge about the problem "is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them"

(Pohl and Hirsch Hadorn, 2008), then this approach should be considered the best to fit. It requires to adequately addressing the complexity of the problems in place and the diversity these problems are perceived from a wide range of stakeholders. The approach needs to be participative, and inclusive. Using specific technique (such as "focus group", to make just one example) experts interact in an open discussion and dialogue. This approach requires grasping the overwhelming amount of information involved, and getting over the specialized languages in each field of expertise. Under these conditions, "researchers need not only in-depth knowledge and know-how of the disciplines involved, but skills in moderation, mediation, association and transfer" (Wikipedia). All participants provide a different perspective, complementing each other and resulting in a more complete description of knowledge than any single person could do alone. In addition, this kind of research enables members from the community to share a set of values that influences and enables the production of knowledge (Miller et al. 2008).

Transdisciplinary research has a number of advantages compared to disciplinary, multidisciplinary, and interdisciplinary research approaches. Some of the advantages are summarized here (Habermann et al., 2013):

- It creates new knowledge by crossing disciplinary boundaries.
- It supports the analysis of complex problems from different perspectives and a detailed understanding of the issues at hand.
- It enables the participants to deal with complexity, uncertainty, change and imperfection.
- It encourages system thinking and guides the participants to look at the whole and its relationship to the parts of an issue.
- It involves researchers and the public in the whole research process. Consequently, it enables the integration of multiple knowledge, overcoming the epistemological barriers between academia and non-academia.
- It enlarges the view and perspective of participants to incorporate issues outside disciplinary boundaries.
- It enables participants to jointly learn about (and understand) complex problems and to facilitate knowledge exchange.
- It targets societal issues or needs and expectations of the society. As a result, it bridges the gap between research and practice.

9. Concept map of research, research topics and their interactions

In order to consolidate a critical mass of researchers and plan the research activities within a suitable time frame, it is very useful to arrange a strategic set of research topics the Unit or Department is interested to. With respect to these topics, the research work will be actively oriented and progressively focused, to reach (as soon as possible) a high scientific profile and a good reputation. For this reason, the research unit should be able to arrange a "concept map" of the research topics and to organize the research interactions among these topics, thus generating information flows and feedback to reinforce these topics and gain an in-depth understanding of the research strategy. This kind of "concept map" could be the starting point in order to establish dedicated research teams within the overall interdisciplinary research unit, each exploring a specific research *niche* and able to exploit better the advantages of scientific specialization, without ever losing sight of the useful connections among the teams.

Concept maps help to create a research strategy; they include the key concepts associated with every topic, and the relationships between the various features of the same topic. A concept map allows brainstorming, identifying what is already known about the topic and what are the knowledge gaps. A concept map is useful to graphically represent and organize ideas, to show how these ideas are related to each other, to reveal new knowledge patterns among concepts, to generate questions research should be focused, to check if all the relevant pieces fit together or anything is missing.

The research *topic* is the general domain in which the research is focused. Research *problems* are drawn from the general domain described by the topic. A research study *goal* "is the major intent or objective of the study used to address the problem" (Creswell, 2005). Research goals essentially detail what the research study intends to do in order to address the problem. Finally, the research goals are operationalized by one or more research *questions*. Research questions "narrow the purpose (or goal) into specific enquiries that the researcher would like answered or addressed in the study" (Creswell, 2005). By attaining answers to those research questions, the study goals are met and a contribution towards solving the problem is made (Leedy and Ormrod, 2005).

According to Kerlinger and Lee (2000), "adequate statement of the research problem is one of the most important parts of research". A clear, precise, and well-structured problem statement leads to a quality research (Jacobs, 1997). The "heart of every research project is the problem. It is paramount to the success of the research effort" (Leedy and Ormrod, 2005). Furthermore, "to see the problem with unwavering clarity and to state it in precise and unmistakable terms is the first requirement in the research process" (Leedy and Ormrod, 2005).

10. Promote the "circulation" of knowledge

To act as a "hub" of knowledge means to promote knowledge exchange. Generally, we use to talk about "knowledge transfer" but, in this case, there is a risk in using this kind of expression. The term "transfer" would mean as if the flow of knowledge is occurring only in one way, namely in the top-down direction, where the *top* is the research institution producing knowledge (the source) and the *down* is the technical organization receiving knowledge and implementing it (the sink), such as enterprises, stakeholders, or society as a whole.

Differently, we should talk about "knowledge exchange" or "knowledge circulation". We need to put in action what the term "*encyclopedias*" originally meant; from the ancient Greek "*enkyklios paideia*", literally "training in a circle" (from *enkyklios* "circular" and *paideia* "education"), knowledge should be put into circulation in the most virtuous way, in order to obtain waves of innovation.

As was specified already, there are several kinds of knowledge that should be identified and understood in the larger transdisciplinary domain. To act as a "hub" will produce a twin benefit: from one hand, it generates an enabling environment for research; from another hand, the collaboration with stakeholders will anchor research to operative applications, thus securing an immediate acceptance. This creates the best conditions to promote social and economic development. To act as a "hub", moreover, also means to activate "bridging" and "linking" initiatives within the scientific community and becoming a promoter of new research perspectives, different approaches, to carry on a vision and new proposals that could generate consensus and become a reference in the research community.

11. Research needs for development

One of the major strength in promoting capacity building in research should be the high level of integration between the two main drivers of scientific and technological innovation, that is to say i) research community and ii) stakeholders, respectively. Linking interactions with the European research community, from one hand, and linking relationships with stakeholders, from the other, are complementary actions, both essential to strength innovation and socio-economic development. Collaborations with leading European research institutions promotes a better integration within the ERA. Apart from knowledge, to implement innovation there is also the need for technology demonstration and testing facilities. Stakeholders, for their part, are absolutely relevant and their involvement in the strategic choices related to research and innovation is a must. The establishment of a formal or informal "stakeholders' network" is very advisable in order to generate agreement and support, triggering and stimulating synergies among productive sectors, to reach a solid economic impact of research, provide advices and orientations, check the interest in promoting regional development.

Capacity building in research should sustain long-lasting structures to support technology transfer and the implementation of know-how into business. Two different but complementary initiatives have been fulfilled by the STAR project (Fig. 3):

- The creation of a university spin-off, to share and transmit scientific know-how in close contact with allied research institutions and the ERA. We have established a "STAR Biomass and Biomaterial Facility Centre", i.e. a specialized laboratory on biomass and biomaterial characterization and an experimental station to operate with pilot plants on energy conversion processes.
- The second initiative is a company consortium named EDEN (the acronym stands for "Energy Demonstration and Education Network") well fit to promote and facilitate technological implementation among the associated firms and to work as a "business incubator" with respect to the local district where the University of Foggia operates.

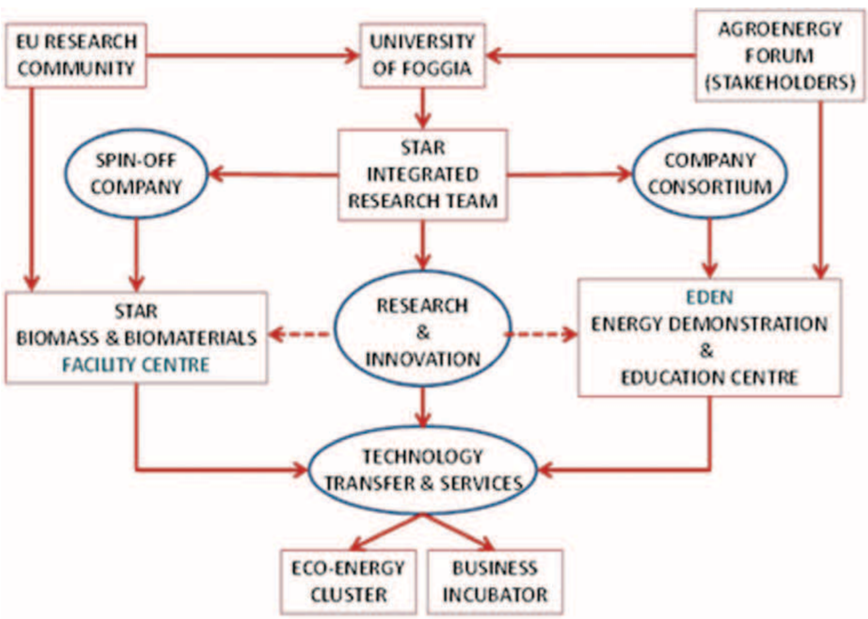

Figure 3. Capacity building in research should sustain long-lasting structures to support technology transfer and the implementation of know-how into business.
A university spin-off (STAR Biomass and Biomaterial Facility Centre) and an Energy Demonstration and Education Network (EDEN Consortium) are two complementary realizations of the STAR project.

According to this overall picture, the "Facility Centre", in the form of a university "spin-off", is aimed mainly to opearte "technology transfer", considering the closer relationship with the European research community via the good position and credibility reached by the STAR interdisciplinary research Unit. On the other side, but in a very complementary fashion, the EDEN Consortium is promoting business with the involvement of the university. This structure is suitable especially to stimulate directly the economic growth, to favour new job placements, to enlarge the possibility to intercept public funding and generate opportunity of sustainable development.

12. Manifesto of the European Mezzogiorno

Starting from the question about what should be the contribution of science and research in the construction of social wellbeing and development, the proposal of a "Manifesto of the European Mezzogiorno" was launched (Koukios and Monteleone, 2014). In order to target a sustainable bio-economy as a new development strategy for the Southern European regions, a Manifesto is proposed to policy- and decision-makers for an immediate action to revitalize the economies of those regions and countries that are currently experiencing a deep and complex systemic crisis. This Manifesto advocates the adoption of a new development model to get the economies and societies of the Southern European Countries (from Portugal, on the West, to Cyprus, on the East) out of the crisis, targeting a sustainable bio-economy. This work, which has taken the form of a Manifesto, is co-authored by scientists and engineers from the five Southern EU countries that are all presently experiencing a deep and complex systemic crisis: Portugal, Spain, Italy, Greece and Cyprus. It advocates the adoption of a new development model, focusing on the target of sustainable bioeconomy, around which other themes and topics will crystallize. Implementing this model will act as a locomotive to get the economies and societies of these countries efficiently out of their crises, and smoothly into greener post-crisis "pastures". The proposal is articulated in ten critical steps or theses for immediate action by the policy- and decision-makers, as well as other key actors within this troubled area of the European Mezzogiorno.

These are the Ten Commandments of the Manifesto:

I. Recognize research and innovation as key development drivers.
II. Give priority to product innovation for sustainable development.
III. Generate innovation power from three "tsunamis": info, bio, nano.
IV. Couple technical innovation with required "soft" research actions.
V. Focus national innovation strategies on green bioeconomy targets.
VI. Consider critical points for deployment of southern european bioeconomies.
VII. Pursue new forms and modes of research in bioeconomy.
VIII. Generate new professional skills by new education and training missions.
IX. Learn to navigate within a complex policy landscape.
X. Plan for international cooperation on green bioeconomy themes.

13. The regional enabling technologies

Innovation plays an important role at regional level, as regions indeed are important engines of economic development. A positive loop promoting social development at regional level can be triggered by strengthening the research capacity applied to the several productive sectors that are related to the bio-based economy (Fig. 4). Promoting a synergy between regional research and innovation policy is perfectly in line with the so-called "triple helix" model (Leydesdorff L., 2012). This model emphasizes various features related to the university "third mission" (apart from education and research), closely related to the academic involvement in socio-economic development of the region, through university technology transfer and entrepreneurship training, in alliance with government policies aimed to strengthen university-industry links. The "triple helix" operates according to an interactive rather than a linear model of innovation: as firms raise their technological level, they engage in higher levels of training and knowledge sharing (Stanford University, 2014). This kind of dynamic triggers a co-evolving sub-set of social systems that interact each other, recursively, thus reshaping their institutional arrangements (Stanford University, 2014).

Obviously, innovation is not uniformly distributed across regions and tends to be spatially concentrated. Even regions with similar economic growth pattern may have different innovation capacities. The Apulia region (in the South-East part of Italy), for example, is still among the Italian regions lagging behind in social and economic development as compared to Central and Northern Italy, and also considering the benchmark of the average European GDP. Despite this general condition, according to the Regional innovation Scoreboard, the Apulia region marks a higher score with respect to other Mediterranean regions, being its innovation performance significantly improved in recent years.

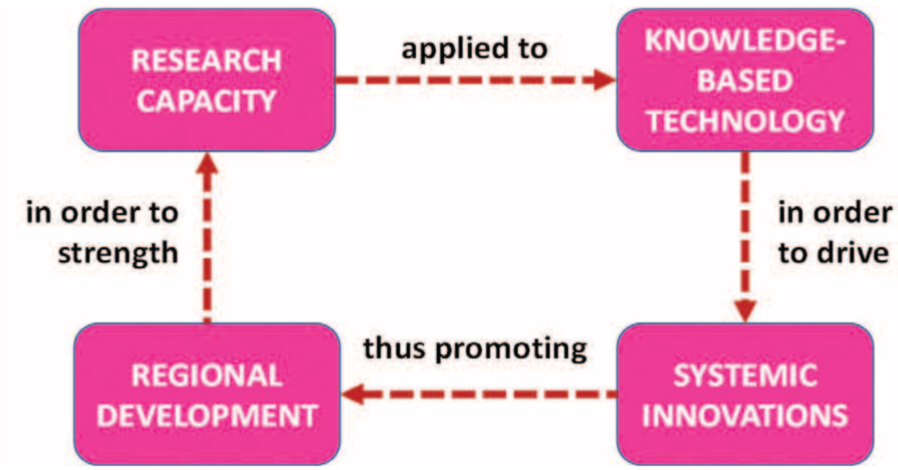

Figure 4. A positive loop promoting social development at regional level can be triggered by strengthening the research capacity applied to the several productive sectors that are related to the bio-based economy.

The *Key Enabling Technologies* (KETs) are considered to be the preferential pathway for a European region to reach the development of new goods and services and the restructuring of industrial processes needed to modernise EU industry and make the transition to a knowledge-based and low carbon resource-efficient economy. Whilst the EU has very good research and development capacities in some key enabling technology areas, it has not been as successful at translating research results into commercialised manufactured goods and services.

Considering this specific regional dimension in selecting the most promising technologies and the best fitting technological improvements, the STAR integrated research Unit has developed a set of technologies as the outcomes of its research activity. These technologies are the following:

Bioresource assessment: Use of spatial analysis and land planning tools to assess biomass potential and design sustainable bioenergy supply chains; biomass sustainability criteria include soil carbon balances and soil fertility aspects.

Biorefineries: A number of biomass processing pathways are investigated, either separate or in technologically integrated schemes. The focus is on the following:

- Anaerobic digestion, with emphasis on biofeedstock pretreatment to enhance efficiency and enlarge the spectrum of substrates to be digested;
- Microalgae cultivation, combined with waste treatment, and integrated with anaerobic digestion for biofuels and fine chemicals production;
- Thermochemical conversion, i.e., biomass pyrolysis and gasification, focusing on biochar, a semi-carbonised biofuel, and a soil carbon-sequestering agent.

Biobased carbon mitigation: This is a key element of the STAR activities, with specific research on the potential for soil carbon sequestration; modelling the soil carbon balance in bioenergy cropping system; and biochar use as a strategy to sequester carbon and contribute to climate change mitigation.

Biosystems management: Systematic activities in these critical fields:

- Methods, tools and databases to support decision-making process in the domain of agro-energy; also, identification of best practices aimed at favouring sustainability, as well as promoting social acceptance of biomass plants at community level;
- Analysis of key drivers and barriers for local, regional and rural “green” development with respect to bioenergy value chains; the financial system is also considered as a possible driver of bioenergy innovation.

The regional strategy for development

An effective and well balanced "regional innovation strategy" should support both innovation demand from companies and empower the innovation offer by research centres. Regional agencies should qualify at the best this kind of matching.

Smart Specialisation Strategy (S3) is the new EU strategic approach to economic development through targeted support to research and innovation. It will be the basis for Structural Fund investments as part of the future Cohesion Policy's contribution to the *Europe 2020* jobs and growth agenda. More generally, smart specialisation involves a process of developing a vision, identifying competitive advantage, setting strategic priorities and making use of smart policies to maximise the knowledge-based development potential of any region, strong or weak, high-tech or low-tech.

There are specific constraints to regional innovation as well as major drivers of it. It is worth to mention just a few of them, specifically the most relevant and frequently observed in less developed regions.

Less developed regions are facing dramatic problems of "brain drain", the best part of younger generations move towards more attractive Countries. To fight this phenomenon is one of the most important action of a wise governance. "Active Principles", "Labs from the Bottom", "Future in Research" are three relevant initiatives launched by the Apulia regional administration specifically addressed to young people. Financing projects designed by young people, promoting their entrepreneurial attitude, strengthening their skills, and fostering the generational turnover within universities are the general objectives of all these instruments.

Regions where people have a favourable attitude and is more positively oriented towards new ideas also has better conditions for both innovation and entrepreneurship. Continuous training and learning, promote the development of new skills, stimulate innovation and encourage the structuring of a participating community. Pre-commercial procurement, incentives and services to create innovative "start-up" are tools that significantly increase the effectiveness to convert good ideas into business.

Finally, a strategic partnership between public and private services, together with a reinforcement of public research infrastructures, and their increasing level of integration into a network of services and facilities, are other relevant targets to enhance research and development and increase the innovation rate at regional level. The regional sponsorship between private companies and public research institutions was carried out through *technology clustering* and the structuring of several *productive districts*. These initiatives facilitated the dialogue between research and technology, academia and companies, increasing the impact of innovation, improving the matching between technology supply and demand.

These are the main initiatives that characterized the policy of the Apulia regional administration and marked a good impact and a relative success with respect to other Italian convergence regions. The new programming period 2014–2020 surely will represents a fundamental test to turn potentials into reality and confirm the regional emerging trend.

Conclusion

"Despite the lip service paid by policy- and other decision-makers in many countries to research and innovation, their role as key drivers of socio-economic development is not only underestimated, but – even worse – it is in practice considered as part of the problem, instead of the solution! So, in their efforts to reduce costs and save resources in order to face the pressing finantial aspects of the crises, government and business tend to sacrifice research and innovation funding". At the same time, "R&D activities are not – as it should – re-oriented to adjust to the particular demands of the crisis-situations" (Koukios and Monteleone, 2014).

In time of crisis, not less, but more emphasis should be paid to research and innovation by government and business. We believe that such a new strategic view is currently growing around Europe, also being catalysed by the just launched Horizon 2020 Programme of the European Union (Koukios and Monteleone, 2014).

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Smart Meters, Grids and Criminality

William J. Nuttall

The Open University, UK

Ettore Bompard

Politecnico di Torino, Italy

Marcelo Masera

IET-JRC, Petten, The Netherlands

Abstract

In this chapter we review and explore ideas connecting the emergence of smart electricity systems with the emergence of new criminal threats and innovations. We stress the systemic risks arising from willful criminal activity associated with future energy distribution systems. We draw upon prior work by Eric Luiijf and others concerning smart grid security. We also acknowledge the contribution of the seventh EC-Framework programme project "Sesame". We close with some recommendations for further European Union research.

1. Introduction

This chapter describes examples of risks of criminal behaviours emerging from future smart meters and smart grids. The link between electricity and crime is, of course, not new. Indeed electricity theft has occurred for as long as there has been electricity distribution. Recently Eric D. Knapp and Raj Samani have provided a cyber security assessment of the electricity smart grid (1). Their work shows threats emerging from the world of computer-crime and they also provide a most helpful glossary of key terms.

The threat of crime necessitates a response. The term "security" encompasses both the goal and the means deployed to achieve that goal. Furthermore virtual networks require physical networks complicating the processes of security. In 2005 Sean Gorman of George Mason University published *Networks, Security and Complexity* (2). In that ground-breaking text he highlighted the vulnerabilities of our new networked world. Those threats are not just cyber-threats nor are they physical infrastructure threats – it is the hybridisation of both domains that is most troubling. The future smart grid sits in such a virtual-physical hybrid space.

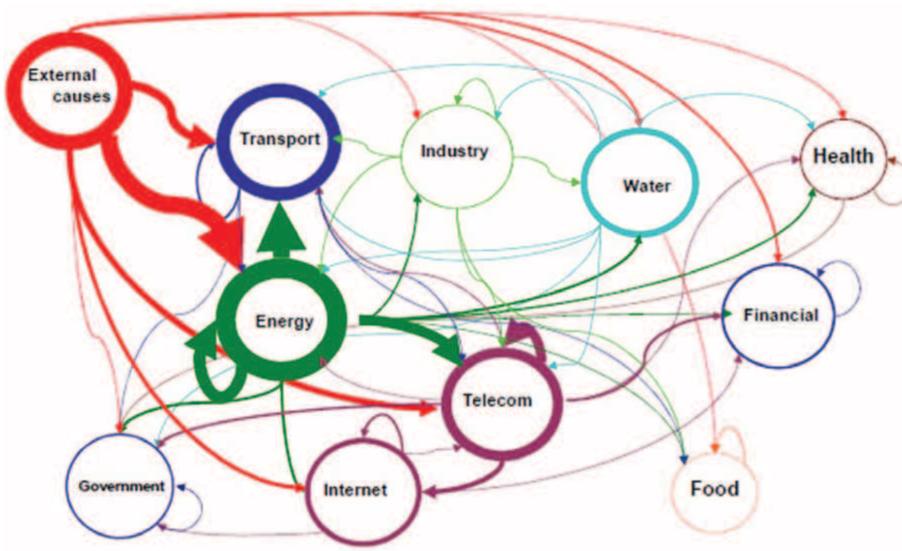

Figure 1: Interdependencies of European Critical Infrastructures. Map assembled by TNO Netherlands 2011. (3)

The smart grid of the future is just one critical infrastructure among many. It links energy provision with internet concerns and as such represents a major security challenge going forward. The centrality and importance of energy critical infrastructures have been considered by TNO in the Netherlands and is illustrated in figure 1.

Elsewhere we have suggested that smart grids may appear complicated, when in fact they are in part “complex”, in the sense that they will reveal emergent phenomena and have elements of self-organisation (4). Smart grid behaviours will clearly be highly-non-linear. We have further suggested that system complexity will lie with and around the smart grid. It is by considering the extended context that some of the richest phenomena are expected to be observed.

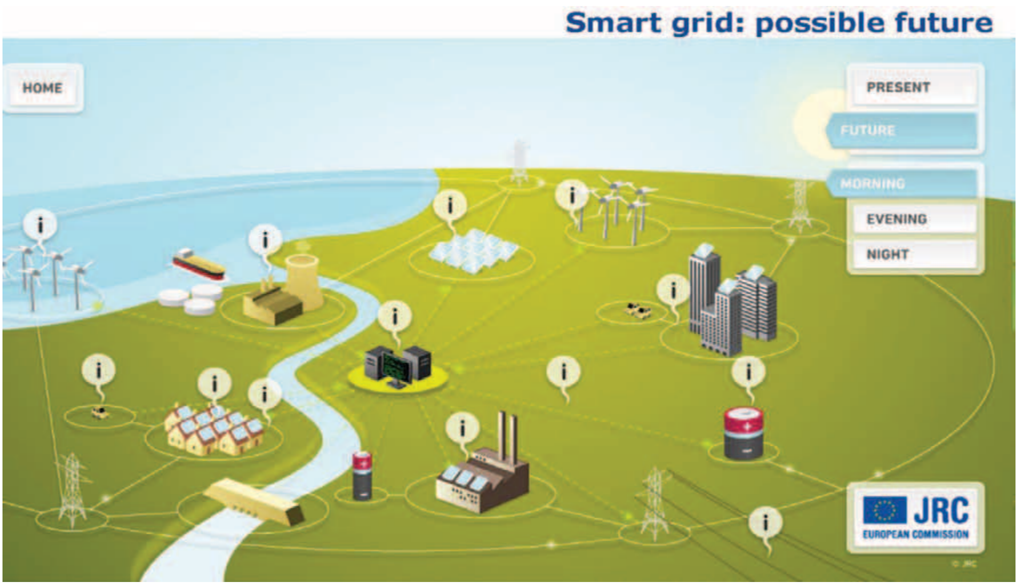

Figure 2. One possible vision of a European smart electricity future, Joint Research Centre, European Commission (4)

Figure 2 illustrates one particular combination of elements comprising the smart grid of the future. Shortle and Chen from George Mason University have commented:

"The smart grid will be characterized by real-time grid awareness and a higher degree of controllability. Sensors will be massively deployed in the many grid components as will communication links among components. The resulting network will be able to operate in a distributed manner independently of central control. For example, if a portion of the grid becomes isolated as an island, it can make local decisions to balance generation and demand within the island to prevent cascading outages. Customers will be able to automatically adjust demand in response to the grid, for example, to reduce the amount of power appliances consumed during high demand periods. Clearly, responsiveness will be greatly enhanced, relative to the current grid.” (5)

Even as a physical system the smart grid risks being misunderstood. The US National Research Council (figure 3) reminds us of the flexibility of electricity distribution systems. This flexibility can be a significant source of security but it can also permit failure modes that more rigid systems would not encounter.

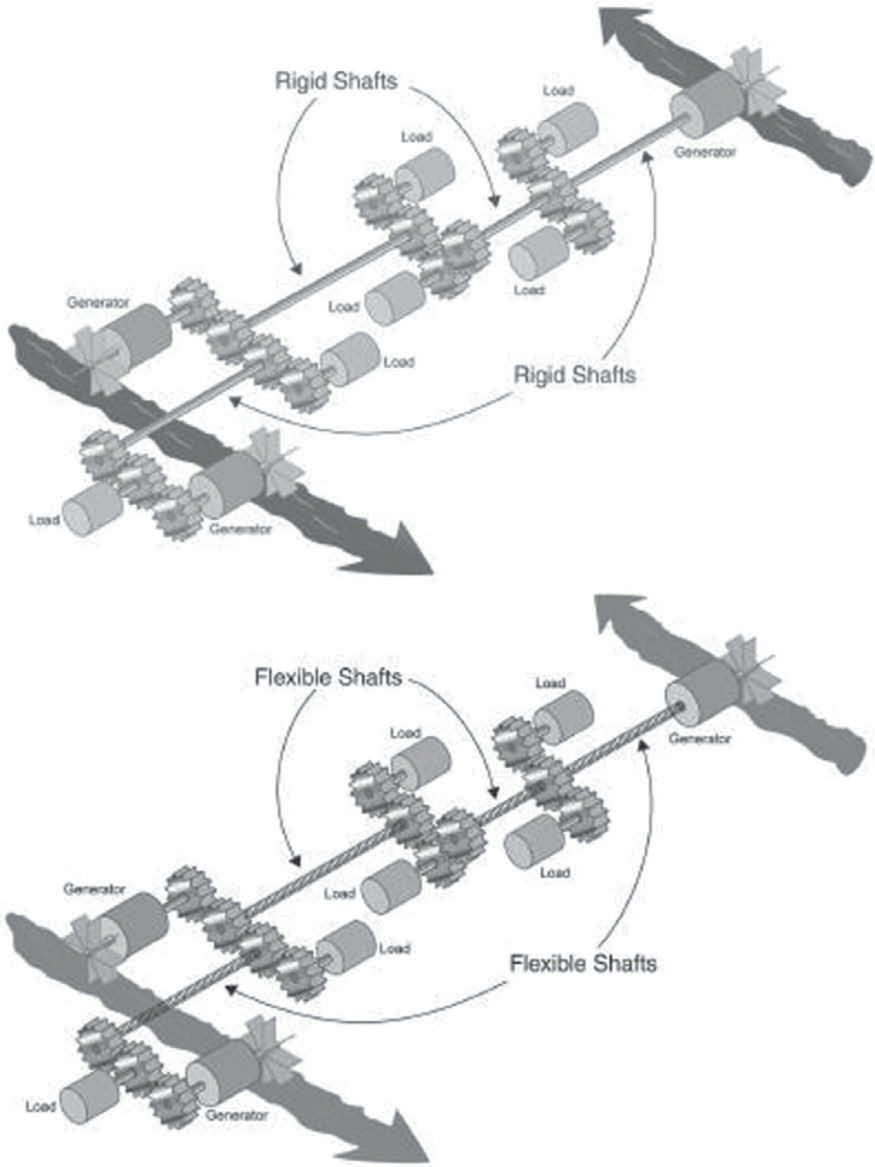

Figure 3: The electricity system is not a rigid machine, but it can get tangled and break. Schematic metaphor from US National Research Council (6)

The smart grid, however, is not just a physical system of electricity grid components. It is not even a combination of such components with pure IT assets, rather (as figure 4 illustrates) it additionally brings in hybrid grid-cyber assets which are arguably unique to the smart grid.

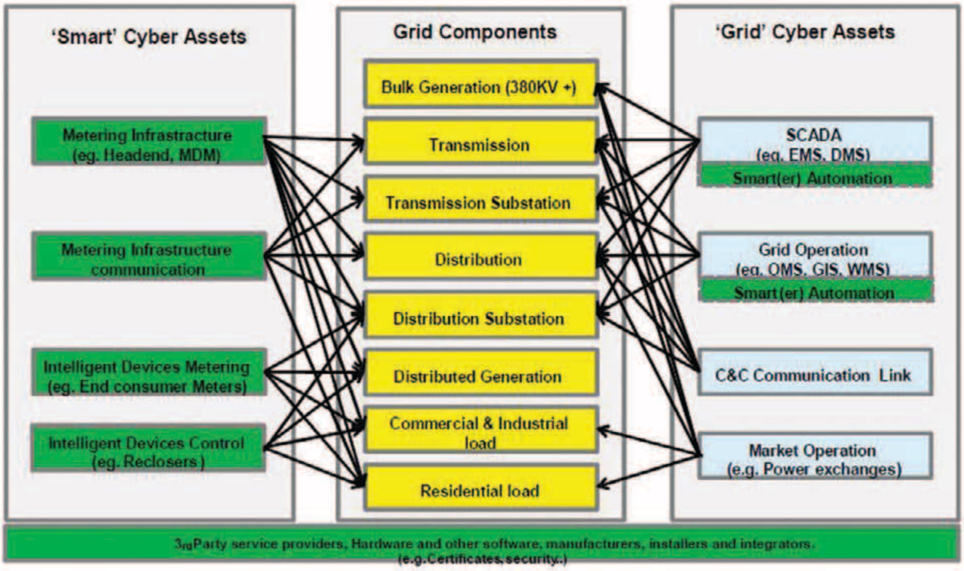

Figure 4: Information and Communication Technology is vital for Smart Grid operation (7).

Earlier we suggested that while the smart grid can be expected to exhibited complexity so can the wider interaction of the smart grid with external considerations. This is partly illustrated by figure 5, but we would go further to include changes such as population dynamics and climate/weather as external linked complexities.

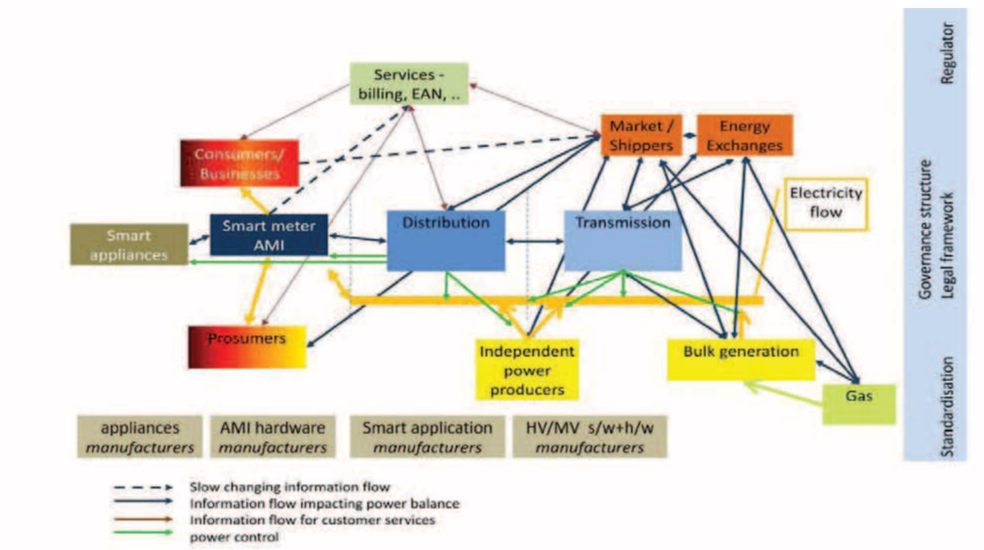

Figure 5. The Smart Grid in a Wider Context (7).

Many people might assert that such systems are complex because they resemble known complex systems. Are comment is stronger than that. We are not saying that they resemble complex systems we are saying that in part, at least, they are complex systems. We cannot prove or evidence our assertion here, rather we posit that the evidence is likely to emerge during the development of smart energy systems in the coming decades. We note and acknowledge the development of ideas under the banner of "*Global Systems Science"* (8) , we see the future energy system being part of such developments.

In order to gain understanding of Smart Grids we see merit in considering them as "multilayer systems" comprising:

- Physical layer of the wires
- Cyber Layer of data
- Social Layer of "prosumers"
- And the Environment layer

2. Examples of crime-related risks and hazards

In this section we describe a series of crime related risks and hazards. Several of these have the potential to reveal or rely-on the inherent complexity of the system. Clearly the main innovation of smart grids is the close integration of information and communications networks with the electricity grid.

This integration of the physical grid and the ICT networks not only subjects the industrial and business sections of the electricity industrial actors to new man-made threats, enormously multiplying the vulnerable points potentially exploited by criminals, but more dangerously exposes end users to security issues that they will not always understand and to which they will always be poorly prepared to counteract.

The systemic risks originated by these phenomena affect all dimensions of the electricity system: the industrial settings normally confined to physical and ICT controlled installations, to interconnections among companies including markets and services, to the end user power systems (from households to commercial users).

It is also important to remember another dimension of the problem is given by the ageing of ICT systems. It is well known the fast rate of obsolescence of those technologies (what requires continuous updates and upgrades), with the concomitant accumulation of identified vulnerabilities. This incessant loss of security offers a fertile ground for criminality. With such considerations in mind let us consider some specific crime-related risks.

I. **Self-interested consumer criminals shifting use in space and time:** for example a criminal might deliberately hack his/her electricity meter to make peak-time usage appear to be off-peak usage. A likely motive would be simple electricity theft. Alternatively a criminal deliberately hacks his/her meter so that the electricity use is attributed to a neighbour (or even someone far away). E.g. to mask high energy demand e.g. for heating by a cannabis farm in a residential neighbourhood. . The simultaneous multiplication of these criminal acts in a certain local area of the network might be easily detectable via supply and billing inconsistencies among the various sources of information, but also it can also contribute to financial losses, n tt only directly but also for the research needed to identify the sources of those incongruities among innumerable data end points, aggregators and centralised databases.

II. **Micro combined heat and power (micro-CHP):** Future northern European scenarios indicate a likelihood of greatly increased average electricity costs. In those countries many homes are heated with natural gas. Fuel poverty and concern for vulnerable consumers are major issues in energy policy, and politics. Those realities militate against aggressive rises in domestic gas prices. We further note global innovations that could make EU gas cheaper. Hence there could be a growing incentive for consumers to implement domestic gas-to-power micro CHP. However, it appears to be a technology that could not easily be retrofitted for carbon capture and storage. As such, a major growth of natural gas micro-CHP would appear to be inconsistent with the EU policy goal of 80 % greenhouse gas emission reductions and micro CHP might need to be rendered illegal. That scenario (noting high electricity prices and relatively low gas prices) could favour illegal and dangerous behaviours in which householders buy a micro turbine and seek to install the system themselves.

III. **Smart Grids and Burglary:** Potential burglars with insight into smart meter usage data can see how a home is being used and can easily see if a home is unoccupied. Some have called such data a "please rob me sign" (9)

But, we note and acknowledge that smart meters might actually reduce burglaries and similar crimes? Michael Kahn quotes David Lewis of TriState EMC: *"We had one lady who saw her usage go up maybe 10, 15 kilowatt-hours," – "She found out her home had been broken into. The reason it was using more electricity was they'd broken the sliding glass door, and the heat was coming on and off." When sheriff's deputies asked the woman when the break-in occurred, she checked her use. "She was able to narrow it down to within a day, because the use went up,"* Lewis said (11).

Levin quotes an industry insider from Ontario utilities as saying: *"Actually I think it's improved certain risks. Instead of [us] sending someone physically to your home once a month, we're not sending anyone to your home, so we've reduced the number of people that are physically coming to your home and perhaps invading the privacy of your space."* (10)

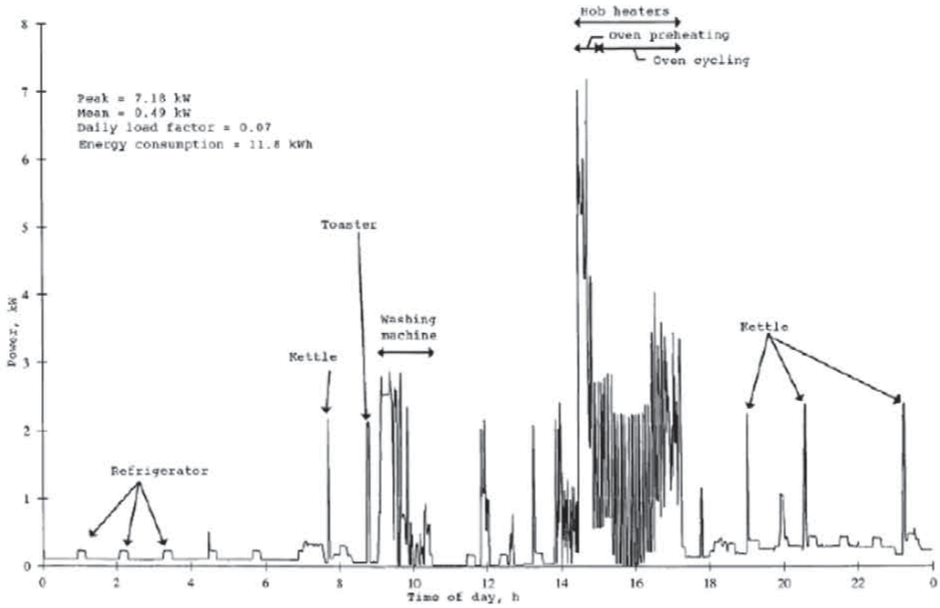

Figure 6. Home Appliance Usage Visible in Electricity Demand When Monitored at High Time Resolution (10).

IV. **Hackers and Cyber Attacks:** EU Expert Group notes some highly-visible examples of possible attacks to Smart Grids … (7) :

- *Deliberate energy market manipulation by changing Smart Grid information about the power demand or supply in a stressed market. In almost real-time markets, a small deviation between power received and payments made might result in significant financial gains for the criminal. Such behaviours will result in difficulties for those attempting to collate and even reconstruct the evidence of criminality.*
- *A physical and/or cyber attack on a (small set of) single-point-of-failure Smart Grid component(s). Knowledge of the topologies of both the physical and ICT networks, or even better both, can facilitate the identification of the causes of serious problems. This all being done with relatively limited attack resources.*
- *Technology Related Anger (TRA) of Smart Grids amplified by a very active (set of) individual(s), e.g. peoples sending tweets like 'Smart Grid equipment radiation is deadly', while lacking a convincing mitigation strategy.*
- *Organised crime manipulating larger sets of consumer premises Smart Grid components or at the data concentrators, e.g. turning a large set of smart appliances off.*
- *Fraudulent information about demand or supply causing automatic measures taken which try to deal with non-existing power flows. Result may be a blackout and/or high financial losses.*

Similarly, perceived threat to the power system as reported by the National Research Council USA and drawing upon work by the Electric Power Research institute USA (6):

Authorization violation: Access by an entity that lacks the proper access rights.

Bypassing controls: Exploitation of system flaws or weaknesses by an authorized user in order to acquire unauthorized privileges.

Denial of service: Deliberate impedance of legitimate access to information.

Eavesdropping: Acquisition of information flows, sometimes by "listening" to radio or wireline transmissions, sometimes by analyzing traffic on a local area network.

Illegitimate use: knowingly or unknowingly intruding on system resources.

Indiscretion: Indiscriminate opening of information files and so on.

Information leakage: Unintentional provision of information to a disguised third party.

Integrity violation: Messages and the computer infrastructure subjected to unauthorized modification or destruction.

Intercept/alter: Intercepting and altering information flows, usually by accessing databases and modifying data.

Masquerade: Posing as an authorized user on a network, the most common method used by hackers to gain access to networks, often enabled by having other users' passwords. A masquerader can view secret information, alter or destroy data, use unauthorized resources, and deny legitimate users access to services.

Replay: Use of information previously captured without necessarily knowing what it means.

Repudiation: Denial by an entity that it undertook some action such as sending a message or receiving information.

Spoof: Occurs when a user or application believes it is using one of the legitimate computer services, while actually performing some different function.

In considering the vulnerability of energy systems, Bruce Averill and Eric Luiijf have commented (12):

"Most non-specific forms of malware will essentially shut down an operating system. Industrial control systems are even more sensitive to malware than your laptop. Of much more concern, however, is systematic exploitation of vulnerabilities by criminal or even terrorist organizations for financial or political gain. In particular, the high value of the commodities flowing through the grids or networks makes them very attractive targets for exploitation by criminal elements, either by means of fraudulent transfer of funds, rerouting of energy flows, or by extortion attempts."

V. **Terrorist Attack on the Electricity System:** Smart networks arguably increase vulnerability to terrorist attack, although one can do much to mitigate such risks by adequate countermeasures. The main factor influencing these vulnerabilities is the need to coordinate the risk mitigation measures among all actors of the electricity system. Any one of them can be the weak link, debilitating the whole system and rendering useless the hardening efforts of all the other actors. For this reason, the vulnerability of the electricity system against terrorist attacks is not only a technical issue, but more importantly a problem of risk governance. The smart grid future links long-standing energy and security risks to the more recent concerns of cyber-attack. We note the work of Tony Craig (Terrorism and National Security (2010)). If terrorists were to succeed in achieving a long-duration blackout to a major city, then the risks to the modern economy are substantial. We note the importance of information technology to retail commerce, transport, water distribution and telecoms (cellular and landline).

Terrorists are aware of electricity systems as potential targets. The Irish Republican Army planned and executed infrastructure attacks from 1939 to 1997. Tony Craig has described how, in 1996 the IRA plan for a long-term blackout of London was foiled by UK security forces (13). The IRA plan was to plant 37 devices to destroy six electricity switching stations around London. If successful, the economic and social disruption would have been substantial. We should also note the activities of the Shining Path group in 1980s Peru as this group also targeted electricity infrastructures.

Increasingly the terrorist threat links to the cyber-crime threat. Inadequate responses to cyber crime threats to the grid have been noted by the EC Expert Group (7):

- Avoid: "BTTWWADI" which stands for "*Because That's The Way We have Always Done It*"
- Prevent Silo Mentalities – horizontal and integrated approaches are better
- Do not rely on Security by Obscurity

VI. **New System Vulnerabilities:** the future of Smart Grids in Europe is closely connected to the increase in reliance on renewable sources of electricity generation especially non-despatchable sources such as solar photovoltaic power and wind energy. As we have described elsewhere electricity, systems relying heavily on such renewable sources pose challenges for maintaining short-term grid security (4). The UK Royal Academy of Engineering has considered the role of wind energy in the future British electricity system and considered carefully the issues of generation adequacy, peak electricity supply and rapid changes in wind availability (14). Very high scenarios for wind energy usage, especially in locally islanded systems raise the additional prospect of insufficient system inertia to easily maintain frequency stability and reactive power supply. These aspects of possible future concern have not been considered by the UK RAE. A system comprising a very high contribution from non-despatchable renewables with low system inertia, coupled with smart system control and finally forming part of a locally self-sufficient system arguably raises, rather than reduces, local system insecurity. Such a vulnerable local system could potentially be an attractive target for criminals or terrorists seeking to cause significant economic disruption.

VII. **Flashmobs and Smart Meters:** We have seen the transformative power of mobile communications and social media technology to traditional street protests. How might future attempts to combine "flashmob" ideas with a desire to attack the smart grid challenge the resilience of future electricity supply? We note that in July 2009 Iranian protesters tried to cause power system collapse by simultaneously turning on appliances. We note the following ideas:

"On Tuesday [7 July 2009] it was just before Ahmadinejad's speech on TV that the messages appeared on Twitter, Facebook and Balatarin [Iranian news sharing site]: 'Please plug in your electrical appliances as soon as Ahmadinejad appears on TV'. It doesn't seem to have worked in the city centre but I was told that the towns of Ahvaz, Ispahan, Racht, Sari and some districts of Karaj were plunged into darkness" Sara (student in Tehran) (15)

3. Conclusions and Recommendations

What do these and other threats mean for the future of our economy and our communities? The paper will close with targeted recommendations as to what must be done to militate against these new risks and are current institutions and powers fit for purpose?

The complexity of the cybersecurity picture presented by smart grids and smart meters appears to require a multiplicity of interventions at different levels. For example:

1. develop a culture of (cyber) security in the electricity sector, so as to make each and every actor aware of his or her role and the potential contribution to meeting the overall risk target, while making sure that company managers and technical staff are trained and accountable for hitting security targets;
2. set security standards and governance mechanisms that facilitate the harmonisation of risk management and analysis across the sector, thereby ensuring a coherent approach;
3. empower the end user with a set of security notions while educating the end users of the future with programmes orientated to the young generations;

4. establish a dialogue among all public and private actors fostering a secure smart grid infrastructure – given the long system timescales, we must remember that the security of tomorrow is being constructed today.

Thinking of smart grids, social media and new social dynamics – *the New Crime is not simply Cyber Crime* … just as the internet is not just an IT system. For many years the banking industry has been subject to anti-money laundering and "know your customer" legal requirements. Social media, however, are replete with fictional personas and identities. Energy companies should be careful when imagining beneficial linkages between social media and smart energy systems. One does not want one's customer to be revealed to be a mere avatar.

Looking squarely at current realities we concur with Joao Martins de Carvalho when he suggests to us that there are currently two main communities of interest concerning risk management for electricity systems and crime. One community is primarily concerned with fraud at the meter level, while the other is fundamentally a community concerned with cyber security. At present it appears that Europe lacks overarching frameworks properly to deal with these security issues in integrated ways. A key step towards improved integration would be to convene gatherings that would attract representatives of both expert communities.

Acknowledgements

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A Skills Approach to Growth of University Spin-off Firms: Export as an Example

Marina van Geenhuizen, Qing Ye

Faculty of Technology, Policy and Management,
TU Delft, Delft, The Netherlands.

Manuel Au-Yong-Oliveira

Department of Economics, Management and Industrial Engineering, University of Aveiro, Campus Universitário de Santiago, 3810–193 Aveiro, Portugal.

Abstract

Universities today are being transformed to play new roles in a global context and their spin-off firms are urged to adapt strategies accordingly and increase international activities. This paper presents an exploratory analysis of the degree of export of such firms in four EU countries, with an emphasis on influence of missing skills. Among the sampled spin-offs, skills that are most frequently lacking and causing a negative influence on growth are skills in gaining financial capital and internationalization skills. We find that a minority (46 percent) of the firms is active in export, with lack of internationalization skills and a limited understanding of economic principles as the main skills factors with a negative influence. In addition, firm-specific factors that constrain exports are young age and small firm size, pointing to the incremental model of export development. Furthermore, the case study analysis revealed a different set of skills requirements for entering export markets compared to growing in these markets. Given the results, we advise to pay sufficient attention to an export plan and an action plan for entering export markets, and to improve presentation skills and negotiation ability abroad to enhance growth in these markets.

Key words:

growth, export; spin-offs; skills; firm profile, European countries

1. A skills approach to spin-off firms' growth

University spin-off firms increasingly attract the attention of researchers and policy-makers alike. Although they constitute just one channel of technology transfer or commercialization, and their direct impact on employment growth tends to be modest, university spin-off firms are seen as potentially important actors because of their positive impact on the regional business infrastructure and services, their informal ways of technology diffusion, and their positive influence on the university's image and reputation (Shane, 2004; Locket et al., 2005; Mustar et al., 2008; Sternberg, 2014).

University spin-off firms (USOs) are high-technology start-ups that bring knowledge created at university to the market. In a more narrow sense, these firms are also started exclusively by university graduates or staff members (Pirnay et al., 2003). Accordingly, and unlike other small high-technology firms, USOs are relatively poor in resources, and in particular lack experience and understanding beyond their technology field, for instance management and marketing, and financial investment (Vohora et al., 2004; Van Geenhuizen and Soetanto, 2009; Soetanto and Van Geenhuizen, 2014). Experience and understanding among managers of spin-off firms, however, may change over time, by increasing the skills level through learning-by-doing and following a specific training, and by replacing founding team members by experienced managers from outside (Visintin and Pittino, 2014).

Entrepreneurial competencies are of significant importance, in particular during the initial phases of a USO, for example with regard to "gaining commercial experience and spending time exploring the commercial opportunity" (Rasmussen et al., 2014, p. 92), which are seen to have major consequences for the subsequent development of spin-offs, as also indicated by Oliveira et al. (2013). Networking capabilities are one of these competences that influence subsequent performance (Walter et al., 2006).

USOs are in particular faced with uncertainty of different kind linked to new technology and novelty in the market, making the entrepreneurial risks higher (De Coster and Butler, 2005; Mohr et al., 2010) and accordingly, educational needs gain in significance. An entrepreneur's education and industry knowledge, for example, previous manufacturing and R&D experience, experience in design, marketing and quality assurance, regulation as well as previous planning experience and knowledge about competitors, are seen to affect USO performance (De Coster and Butler, 2005; Colombo and Grilli, 2005, 2010; Ganotakis and Love, 2012) and so require an additional emphasis in development and training programs.

Furthermore, the involvement of USOs in local innovation networks has been a subject in literature, namely "their catalyzing role to knowledge creation and transfer in innovation networks" (Pérez and Sanchez, 2003). However, as knowledge production and customer markets are becoming increasingly global, with interaction over larger distances from Europe towards Japan, Korea, China and Brazil (Audretsch et al., 2014; EC, 2011; OECD, 2012), research on USOs also needs to focus on the skills and competences that enable the internationalization of the business activities of these young firms.

There is a lot of research on the internationalization and growth of high-technology SMEs, more recently under the label of human capital and absorptive capacity (e.g. de Jong and Freel, 2010; Clercq et al., 2012; Fletcher and Harris, 2012; Liu, 2012). In fact, quite recently, the skills level has been addressed extensively in relation to exports (Brambilla et al. 2012; Ganotakis and Love, 2012).

This paper adopts a skills approach to growth, in particular to exports, which implies attention to abilities of managers that can be developed and further improved. This is in contrast to the approach which deals with abilities that are innate and largely fixed, although the two approaches cannot be fully separated. Broadly drawing on the work by Katz (2009) we may consider technical (processes and techniques connected to the area of the firm), human (effective interaction with people inside and outside the firm) and conceptual issues (formulation of ideas, problem solving and planning, etc.). To our knowledge and based upon a systematic scan (Saur-Amaral, 2010), such research has never focused specifically on USO growth and internationalization performance and training needs. Against these backgrounds, the following research questions will be addressed in this paper:

1. Which skills are most important to growth of university spin-off firms?
2. To what extent are university spin-off firms engaged in exports and what is the influence of skills that are lacking? Which other factors are involved?
3. In which way can the outcomes regarding lacking skills be translated into specific training?

In answering these questions, we use a mixture of existing literature and original empirical work, by drawing on a sample of 85 spin-off firms in four countries (Finland, Netherlands, Poland and Portugal), including two in-depth case studies of selected firms, and various pilots on internationalization training tested in practice.

2. The need for developing exports

Various circumstances make the need for exports among small high-technology firms more urgent today, for instance the progressive disappearance of barriers and borders within the European Union (EU), exposing all EU firms to new market opportunities but also to new international competition. In addition, specialized markets are increasingly emerging at far distance from Europe, Brazil, Russia, India, China and Korea, etc. (OECD, 2012).

The need for internationalization of high-technology SMEs is evident if we look at the differences in business performance (EC, 2011). In the EU, internationally active SMEs create more jobs and are more innovative. Most recently, it appeared, specifically with regard to university spin-off firms, that employing international knowledge relationships, among other things, tends to increase growth, both in terms of employment and turnover (Taheri, 2013). However, the road to extending economic activities abroad, for instance in manufacturing activity (outsourcing) and exports is littered with stumbling blocks. University spin-off firms are often poor in resources and skills/capabilities, due to their young age and one-sided (technology) origin (Van Geenhuizen and Soetanto, 2009; Van Geenhuizen and Ye, 2012a), and this prevent them to remove the barriers concerned.

Drawing on research by the UK Department for Business Innovation & Skills (BIS) (2010), the following three types of barriers can be distinguished. First, there are *resource barriers*, like a lack of financial and human capital (absorptive capacity) to be able to identify opportunities and practical options, leading to a poor 'readiness' for internationalization (Van Geenhuizen and Ye, 2012b). Secondly, there are *information and network barriers,* indicating a lack of knowledge regarding opportunities in foreign markets and market segments, and an inability to contact potential outsourcing partners and customers and establish an initial dialog, and to build trustworthy relationships with key decision-makers (e.g. Liu, 2012). This type of barrier also includes *cultural barriers*, like a lack of awareness and knowledge of local cultural norms, as well as language barriers. The third type of barriers is *legal and procedural barriers*, including difficulties in dealing with laws, financial and tax regulations, product standards, and patent and trademark issues. The strength of such barriers may vary per economic sector, for example, in medical biotechnology, such barriers are relatively strong, due to different rules for registration, pricing, reimbursement, etc., between countries (Nooten, 2012). Instead of barriers, the CAGE framework (Ghemawat, 2007) looks at various distances, such as cultural distance and administrative or political distance, when considering cross-border strategies.

All the barrier types mentioned above have a dynamic character, meaning that they grow/change with progress in exports and with the growth of the firm in question. Barriers also tend to be different for the various entry modes in export, indirectly present in the foreign country using an agent or directly present in an own site or office. It is a serious challenge for USOs to overcome these barriers and reap the rewards of internationalization but the existing literature still lacks models aimed specifically at USOs, facing unique characteristics, resources and needs, and existing models tend to concentrate on larger firms. However, two development models have been designed for young ventures in general: the model of incremental internationalization and the born-global model.

Gaining sufficient resources to 'invest' in internationalization over time is at the heart of the model of incremental internationalization (Johanson and Vahlne, 1977, 2003), in which small firms first establish domestic markets and then turn to other countries. By contrast, the born-global model assumes an immediate entry into foreign markets, when or shortly after the firm is established (e.g., Oviatt and McDougall, 1994; Andersson and Wictor, 2003; Knight et al., 2004). The processes that make new ventures born-global, are seen to be connected to pre-existing networks, possibly coupled with newly established ones, but also a strong pressure from relatively small domestic markets. Born-globals are receiving a growing attention today (Eurofound, 2012), but lack of a harmonized definition of these specific ventures tends to complicate research and make it harder to design policies to enhance their growth. In the context of this study, we assume that incremental internationalization and born-global development require different sets of skills and competences.

3. Methodological aspects

The sample of USOs used in the analysis is taken from the framework of the Spin-Up study, a European project aimed at picturing key entrepreneurial skills in performance of USOs, particularly skills they lack, in order to develop an effective training and coaching program (URL: www.spin-up.eu). The countries involved are Finland, the Netherlands, Poland and Portugal.

There are many definitions of USOs (Djokovic and Souitaris, 2008; Bathelt et al., 2010). We use the definition suggested by Pirnay et al. (2003): newly and independently established firms that bring university knowledge to market. This definition emphasizes the knowledge/technology link with the university, and the availability of technology/innovation skills among the founders, usually university staff and/or university graduates. In composing the sample (Van Geenhuizen and Ye, 2012a; Oliveira et al., 2013) two selections were made. To avoid a large differentiation, age limits were set at 2 and 10 years, with the exception of those sectors where the development and marketing of inventions are relatively slowly, for instance medical life sciences and material (nano) science (around 15 years). With regard to size/growth, the sample represents the following variation: small as well as larger firms, and growing firms as well as firms that are stable or declining, to allow us to assess a 'causal' relationship between the absence/presence of particular skills (experience) and different growth patterns, including amount of exports activity. The data were collected in 2011 using a full questionnaire in face-to-face interviews with the CEO or other manager, and a condensed questionnaire in a web-based/e-mail survey in addition to the websites of the USOs.

The sample size including valid responses on size and growth is 99, but on internationalization and export activity and on skills this is 85. The non-response of 14.1 percent is connected with a difficulty in filling in the more detailed part of the web-based questionnaire, and seems no reason for concern with regard to bias. Responses per country are as follows: Finland (21 percent), Netherlands (33 percent), Poland (16 percent) and Portugal (29 percent), which means there is an overrepresentation in the sample of spin-offs in the Netherlands and Portugal. Furthermore, the data is largely based on self-estimation of CEOs, meaning that the results on lacking skills could be influenced by over-estimation or under-estimation. However, in the in-depth interviews, various control questions were included, reducing the chance for self-estimation bias.

4.Growth, missing skills and degree of export

4.1 Growth and skills influencing growth

In general spin-off firms from universities in Europe do survive over longer times, but grow relatively slowly (Mustar et al., 2008). For the sampled spin-offs, we measure an annual growth of 1.6 FTE (full time equivalent) in the years since their start up to 2011 (Table 1). On average their employment size in FTE's is 10.9, whereas almost half (48 per cent) produces a yearly turnover smaller than 100.000 Euro and only 27 per cent exceed a yearly turnover of 300.000 Euro. Although there are certainly spin-offs as positive outliers, as evidenced by a high standard deviation of employment size, these numbers confirm the existing picture of a relatively slow growth.

Table 1 Growth and size indicators of spin-off firms (2011) (N=99)

Indicator	
Annual job growth (start – 2011) (average)	1.6 FTE (2.5)a
Employment size (2011) (average)	10.9 FTE (20.5)a
Turnover size (2011) <100.000 Euro (share all firms) >300.000 Euro (share all firms)	 48 % 27 %

a) Standard deviation

Source: Van Geenhuizen and Ye, 2012a

The presence of a set of 17 selected skills was explored in the Spin-Up study, by using a five-point scale, from 1 (total absence) to 5 (full presence). We qualify skills receiving a score of 1 or 2 as lacking. The top five skills that are lacking as well as lacking skills that have a strong influence on growth, as perceived by the CEOs, are shown in Table 2. Both internationalization skills and skills in financial management tend to be most often lacking skills in our sample.

Of the five most frequently lacking skills four are perceived by CEOs as critical for growth, namely internationalization skills, skills in gaining financial capital, skills in financial management and HRM skills, while sales and marketing skills are added. One skill is not perceived as critical for growth (intellectual ownership protection). The high rankings of internationalization skills justify our attention to internationalization as an area of lacking skills and barriers, but also as one of the main pathways to grow.

Table 2 Skills that are most frequently lacking (N=85)

Rank	Lacking skills	Rank	Lacking skills hampering growth (in CEO perception)
1/2	Internationalization	1	Gaining financial capital
1/2	Gaining financial capital	2	Internationalization
3	Human resources management	3	Sales
4	Protection Intellectual ownership	4	Financial management
5	Financial management	5/6	Marketing
		5/6	Human resources management (HRM)

Source: Van Geenhuizen and Ye, 2012a

4.2 Internationalization skills and export

Internationalization skills (Table 3) tend to be absent among almost one third of the 85 USOs in our sample (31 percent), while these skills tend to be present or strongly present among 45 percent of the sampled firms. In addition, 25 percent of the USOs give a neutral response. Furthermore, the importance of internationalization is recognized by 14 percent of the firms, who are convinced that lacking internationalization skills is or will be severely hampering their growth in the near future. Although no comparative research is available, this share seems to be somewhat low, indicating a potential absence of a feeling of urgency regarding internationalization, including export.

Table 3. Scores on internationalization skills (N = 85)

Scores	Share of USOs (%)
1 (total absence)	10.6
2	20.0
3 (neutral)	24.7
4	23.5
5 (strong presence)	21.2
All spin-offs	100.0
Share of spin-offs recognizing that missing internationalization (skills) may hamper growth	14.1

Lacking internationalization skills can be illustrated with experience in Portugal. In this country, where there have been serious internal economic problems, with the implementation of a number of austerity measures overseen by international creditors, in 2011, the domestic market has been adversely affected. This means that internationalizing is the only way for a number of Portuguese companies to survive, including some of the USOs in our sample. One CEO in particular stated that internationalization skills were lacking in his management team and that sharing experiences with the CEOs of other USOs would be very beneficial, in particular with regard to ways to internationalize to certain markets (internationalization/entry plan, legal and fiscal aspects to take into account, what mistakes to avoid, what best practices to follow, as well as the sharing of international contacts, among other things) such as in Brazil, a former Portuguese colony which is culturally close to Portugal, and where they speak the same language.

Among the USOs in the sample, 56 percent is not active in export while 44 percent is active (Table 4). Among the last category, 19 percent reach a small share of export in turnover (1 and 30 percent), 8 percent a larger share (30 to 60 percent), and 17 percent a substantial share of more than 60 percent. The share of USOs active in export of 44 percent is larger than the overall figure in Europe among SMEs, which is 25 percent (EC, 2011), indicating smaller domestic markets for USOs, most probably due to technology specialization, but there is room for important improvement. On the other hand, the small share of substantial exports (17 percent) can be understood by considering the early development stage of USOs, often producing small sales, and the comprehensive decisions involved in shaping exports, like selecting the country and the market segments, the use of agents and market channels, product specification/standards, and adjustments to local needs, etc.

Table 4. Degree of export by USOs (N=85)

Exports (share of turnover)	Share of USOs (%)
No export	56
1–30 %	19
30–60 %	8
>60 %	17

5. Influences on exports

5.1 Model structure

In this section, the model structure and estimation results on exports are presented. We distinguish two sets of factors, first, the USOs' broad firm profile which we use as control variables, and secondly, various highly relevant skills that are lacking (core of the model). Establishing export relations requires the use of available resources (Wiklund and Shepherd, 2003; Lavie, 2006; Barney and Clark, 2007), for instance, having sufficient management time and investment capital, being familiar with certain networks. We may assume differences in available resources (or limitations) according to firm age and size, and pre-start experience (cross-cultural). Also, we may assume an influence from the country of location of the spin-off firms. In addition, we take differences in drivers and needs for developing export into account according to economic sector. These factors are discussed in more detail below, to start with the control factors.

In the 'incremental' model, it is recognized that internationalization increases with the age of new ventures, through the progressive accumulation of experience and generation of profitability, the latter allowing for the internal financing of various steps in internationalization. For example, face-to-face sales meetings abroad can be very expensive, as can the presence at international trade shows as a participant/exhibitor with a trade show team and stand. Later steps, such as setting up a warehouse with products closer to points of sale to reduce delivery times and shipping costs to customers, is a step that is normally speaking only possible after a number of years of operation and some success on the domestic side, but 'born-globals' do this already at or shortly after their inception. In addition, accumulated experience (learning) of an organization tends to increase with the age of the organization, but may also be stronger when the firm has a larger size (Zahra and George, 2002; Zahra, 2005; Xia, 2013), which also basically means greater capacity in the sense of available man-hours, which is needed for export development, including visiting international fairs and export exhibitions, and dealing with intermediary institutions (export agents) etc. The previous reasoning makes us decide to take both age and size as control factors.

A third control factor is the presence of pre-start working experience, specifically its cross-cultural character. Pre-start experience of members of the founding team may be a valuable resource in developing export if cross-cultural aspects are involved (Reuber and Fisher, 1997). Examples are being familiar with different (direct or more indirect) 'ways of communication' and dealing with different degrees of hierarchy in working relations and in the relationship with government officials. In general, the availability of pre-start experience and subsequent learning is increasingly addressed in recent literature on new ventures (e.g. Colombo and Grilli, 2005, 2010; Clercq et al., 2012; Ganotakis and Love, 2012). Next, we mention the industry sector in which the USOs are active, because of different ways of learning and levels of specialization. We draw a distinction between science-based sectors and other sectors (Asheim et al., 2007; Jensen et al. 2007; Tidd and Bessant, 2013). In science-based sectors, the specialization tends to be stronger meaning that when realizing growth, the spin-offs are forced to develop markets abroad. In addition, learning in these sectors deals with laws of nature and tends to be globally oriented due to the universal character of science, different from sectors with mainly adaptive (problem-oriented) learning, meaning a much easier step to export for spin-offs in science-based sectors.

As a last control variable, country is included, because internationalization may be pushed more strongly in small and open economies. For example, the Dutch and Finnish domestic economies tend to be small and open, while Portugal, which has a small domestic market in which most recently demand has seriously dropped, needs to develop a higher degree of export.

The core set of factors of the model is that of skills and competences, as export or its growth may vary due to people's ability to overcome various barriers involved (Ganotakis and Love, 2012). The skills selected in the model are derived from the Spin-Up data-base using a systematic scan on the basis of correlation of a full set of 17 entrepreneurial skills with exports, indicating a high correlation for three of them. Accordingly, internationalization skills, sales skills, and skills in the economic principles of high-tech entrepreneurship are included in the model.

5.2 Descriptive statistics

With regard to the control variables (profile), USOs in our sample, on average, are seven years old and have a size of almost 11 FTE's (full time equivalent) (Table 5). With regard to size, there is a large standard deviation (22), indicating a strong differentiation within the sample, with a range from 0.5 to 175 FTE's. The spin-offs are mainly active in non-science-based sectors (64 percent), with a dominance of ICT, including software technology (40 percent). Firms active in science-based sectors are in a minority (36 percent) and mainly involved in life sciences (14 percent), focusing on new medicines, but also on products for advanced medical processes, like geno-typing. In addition, material science designed to develop, for example, new batteries, diodes, and membranes, is also part of the science-based sector in the sample. Furthermore, the availability of cross-cultural experience, gained in internationally oriented PhD research, a career as an international scientist or as a manager in an international firm (often abroad), turns out to be a varying factor among the USOs in the sample, depending, among other things, on the number of management team members with that kind of experience. The average accumulated years per USO amounts to about 15, with a standard deviation of 21, in a range between 0 to 80 years, indicating that there are some USOs without any cross-cultural experience and some where all management team members have that kind of experience. An abundant cross-cultural experience is often found in science-based firms after some years, as a result of various rounds of 'professionalizing' the management team, replacing young founders by more experienced business professionals, often from abroad.

With regard to skills, internationalization has the lowest score of the three selected skills, but also the largest standard deviation, indicating relatively large differences among the USOs (Table 5). In fact, however, the average scores of the three skills are relatively close (about 3.35).

Table 5. Descriptive statistics

Descriptive	
Number of USOs	85
Dependent variables	
Size of export: share in exports in 2011 (% of turnover)	Avg.: 0.22; Sd.: 0.35; min-max range: 0–1
Controls: USOs' profile	
Firm age: continuous variable as number of years since foundation	Avg.: 6.67; Sd.: 3.43; min-max: 2–17
Firm size (fte) (log-transformed in the model)	Avg.: 11.45; Sd.: 21.98 min-max: 0.5–175
Cross-cultural experience: continuous variable as added sum of years of founders' cross-cultural experience in management or technology *(log transformation in model)	Avg.: 14.80; Sd.: 20.75; min-max range: 0–80
Sector: variable in two categories, science-based (1) versus non-science based (0)	Science-based: 36 %; Non-science based: 64 %
Country: dummy variable indicating country	Finland: 21 %; Poland: 16 %; Portugal: 29 %; NL: 33 %
Selected missing skills	
Internationalization skills: doing international business, crossing cultural borders	Avg.: 3.25; Sd.: 1.29; min-max range:1–5
Sales skills: negotiation, contract arrangement and control	Avg.: 3.33; Sd.: 0.90; min-max range:1–5
Understanding economic principles of high-tech business: e.g. cost-profit relations, economic indicators, risk-taking	Avg.: 3.47; Sd.: 1.03; min-max range:1–5

5.3 Estimation results

We estimate three models for exports (Table 6), with the first including the control variables on the USOs' profile, the second including the set of three skills and the last as the full mode. We performed the standard checks to satisfy rules of multiple regression analysis, and there appears to be no reason for concern (Annex A and Annex B). Multi-collinearity draws some attention in the interpretation of the full model, due to the relatively strong correlation between pre-start cross-cultural experience and internationalization skills (a coefficient of 0.44) on the one hand, and this experience and firm size (0.41) on the other hand.

We first discuss the set of control variables (USOs' profile) in Model 1. The beta-coefficient of firm size is positive and significant whereas with regard to the remaining profile factors, the model including the country does not show any other significant influence. With regard to lacking skills (Model 2), the beta-coefficients of internationalization skills are negative and significant, and this holds also true for skills on economic principles. Overall, adding lacking skills to the model of the profile factors produces a considerable improvement of R^2 of 0.11 in the full model (Model 3).

The trends observed regarding the influence of the skill level can be understood as follows:

- Lacking skills tend to influence export strong relative to the USOs' profile. This underlines the consistency of the study and indicates the importance of typical knowledge gaps on internationalization like how to start and implement practical internationalization and export, how to attract capital to finance export, and how to access market channels and use marketing tools, including negotiations abroad.
- A lower understanding of economic principles tends to reduce the propensity for exports, which indicates the influence of some specific barriers connected following from a lack of reading/assessing economic indicators of firms, particularly costs-profits and risk of export, and of understanding principles of competition in markets abroad.

Table 6 Results of estimation of degree of export

	Export		
	1	2	3
	(s.e.)	(s.e.)	(s.e.)
Controls: USO profile			
Firm age	0.12 (0.07) a)		0.13 (0.07)*
Firm size a)	0.09 (0.04)**		0.07 (0.04)*
Cross-cultural experience	0.02 (0.03)		-0.02 (0.03)
Sector (science-based = 1)	0.06 (0.09)		0.03 (0.08)
Finland (baseline)	-		-
Poland	0.00 (0.12)		0.06 (0.12)
Portugal	-0.05 (0.11)		0.04 (0.11)
The Netherlands	0.01 (0.10)		0.04 (0.10)

Absent skills			
Internationalization		-0.09 (0.03)***	-0.09 (0.03)**
Sales		0.02 (0.04)	0.02 (0.04)
Economic principles		-0.08 (0.04)**	-0.07 (0.04)*
N	84#	85	84 b)
F	2.73**	6.34***	3.23***
R^2	0.20	0.19	0.31
Root MSE	0.33	0.32	0.31

a) In an experiment, excluding size, age and cross-cultural experience turn out to be significant.
b) One spin-off is missing for cross-cultural experience
* p<0.1; ** p<0.05; *** p<0.01

6. In-depth insights concerning skills

The two case studies selected for the analysis are strongly contrasting and almost extremes (Table 7).

Table 7. Selection framework of two case-studies

Spin-off (size in 2011)	Exports (2011)	Age (2011)	Cross-cultural experience	Science-based/ otherwise	Internat. Skills Score	Economic principles skills Score
Case study I (7 fte)	No export	3 years	None	Non-science	1	5
Case study II (33 fte)	90 % export	7 years	20 years (2 managers)	Science/ non-science (fiber optic sensors monitoring systems)	5	4

a) Excluding predecessor firm

Case study I

This firm, based in the Netherlands, is a typical combination of small size, young age, lack of pre-start cross-cultural experience, non-science-based activity, and absence of internationalization skills (score of 1), all pointing toward an absence of export. The firm, active in design and producing hygienic products in elderly care as a wireless notification system, focuses entirely on the domestic market, thereby representing small and young USOs that first want to establish a solid position on the domestic market, actually lacking the required resources and internationalization skills. The firm is not yet profitable, meaning that there is no capital available to set up the activities preparing for export, and, due to a quick domestic growth, the firm is also lacking management time. However, the market for products/systems of the firm is clearly growing due to ageing of the population and making elderly care more efficient.

Although the product/system has been patented – similar products could be designed abroad and become a serious threat. Accordingly, instead of following the 'stepwise' model, the firm is advised to develop the domestic and some foreign markets (similar to the Dutch elderly care market, like Germany, the UK and Scandinavia) simultaneously. This would mean obtaining the necessary financial support from a solid investor and adding at least one new manager to the team, particularly one with strong cross-cultural experience, who is familiar with the care market for the elderly and can bridge the information and network barriers. If this is not affordable, customized training/consultancy may work, particularly using the experience of colleagues in developing an action plan.

Case study II

This spin-off, based in Portugal, is an example of a medium size, medium age, intermediate level of cross-cultural experience, and high scores on skills, pointing to relatively high levels of internationalization. The original base of the firm is physics, but the application is used in various practical monitoring and detection systems, like concerning vibration (power generators) and temperature (telecom satellites). The firm develops and produces advanced monitoring systems for any structure – highly sensitive and precise, with an excellent performance in hazard environments, and it provides a complete offering of sensors, as well as measurement units and software packages, that are sold in countries such as Brazil, Germany, Portugal and Spain. Exports represent 96 percent of the total turnover (up from 90 percent in 2011).

The spin-off has had three external CEOs in the recent past, to compensate for the lack of management experience and to boost sales. The current CEO has some previous international/cross-cultural work experience (a PhD in the US) as well as other types of international experience, through for example participation in European projects. It is worth noting that the highly developed internationalization skills of the current CEO were *acquired through experience* rather than by taking an academic course, for example. Accordingly, he feels having gone from the technical side of the operation to the commercial side of the firm, although the two are strongly linked – sales encompasses a large technical component. Marketing and sales (with five people in total) have been recently reinforced. The main barrier to a stabilization of international growth follows from the specific technology, which is not well-known abroad, and from different certification requirements, which are expensive and time-consuming to fulfill.

If we compare the two spin-off firms as they are today, we observe a situation of being at the start of an incremental development of export activity versus a situation of almost exclusive export short after firm establishment. The last one's product seems highly specialized such that immediate orientation of the firm on export was a 'must'. In the 1st case study, the skills needed are typically the ones for selecting the best countries for a product/service, setting up networks providing access to the markets, deal with cultural differences (business culture, product/service requirements), setting a price abroad, eventually dealing with regulation, etc. Spin-offs like these have to increase awareness on what is needed (which activities) to get export from the ground, what the costs and benefits are and what the risks could be. These spin-offs can be supported with training on elaborating an *export plan* and derived from that an action plan, which requires coordination and planning, and financial investment and investment of personnel.

The 2nd case study in the current situation is facing a 'struggle' to keep growing abroad, which tends to require different skills compared with entering export markets (Ganotakis and Love, 2012). In our case study, this is partially solved by increasing marketing and sales personnel in the firm, but some other important skills are also needed. We mention to be able to convincingly communicate the unique benefits of the product abroad and to negotiate and gain the best contracts. Accordingly, for growth in export markets, the level of education of the manager seems more important. Of course, specialists could be attracted on a temporary basis, but such skills can also be acquired by managers in personalized training in a small group setting, where they learn from each other in simulated reality in negotiation. In addition, skills in certification or other regulation are highly specific and could be outsourced to a specialist or pooled between spin-offs with the same type of regulatory requirements in a collaborative setting which may require a new attitude and collaboration skills.

7. Conclusion

Internationalization has been widely studied among (high-tech) SMEs, in recent years particularly using learning and absorptive capacity frameworks, but the specific class of university spin-offs has – to our knowledge – never been the subject of such studies. The attempt to map the degree of exports and the identification of the influence of specific skill factors, makes this study the first of its kind. We used a sample of almost 100 spin-offs carefully selected in four countries to represent different theoretical positions of the firms and we analyzed two contrasting case studies.

Overall, the sampled spin-off firms did not show a quick growth, rather they develop slowly, and this can be ascribed to various skills that are lacking. The two most important ones are skills in gaining financial capital and a set of internationalization skills. Model estimation indicated that missing internationalization skills also has a negative influence on export activity, with 46 percent of the sampled spin-offs involved in this activity. In addition, missing skills on economic principles, like pricing, competition, costs and benefits, also tend to constrain export activity. Furthermore, the two case studies confirmed these broad patterns, but also revealed differences in missing skills between an incremental path of entering export markets compared to growing in already accessed export markets. So-far badly identified skills required in the last situation include convincing communication about uniqueness of the product/service and effective negotiation on contracts.

In terms of the generalization of the empirical results of this study, we acknowledge that the study was based on a relatively small sample, preventing statistical analysis and conclusions. The spin-offs were, however, carefully selected to represent various 'structural' positions of European university spin-off firms, like the young and small firms, the science-based firms, and firms with poor cross-cultural experience and poor internationalization skills. In future research, the sample size could be increased to yield results that can be generalized statistically, as well as enabling a thorough testing of the results of this study. The model could also be extended to include influences on export activity that have remained outside our analysis, such as the innovation level of the firm (e.g. Love and Roper, 2013). In addition, adopting a longitudinal approach in following the spin-offs over a longer period of time, would make it possible to identify the impact of improving skills and acceleration of foreign market access and export, as well as the emergence of the need for new skills with regard to growth in export markets (Ganotakis and Love, 2012).

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Annex A

		1	2	3	4	5	6	7	8
1	Export	1.00							
2	Firm age	0.28*	1.00						
3	Firm size	0.38*	0.28*	1.00					
4	Cross-culture experience	0.25*	0.13	0.41*	1.00				
5	Sector (science-based=1)	0.19	0.06	0.14	0.28*	1.00			
6	Country of location	-0.03	-0.08	0.00	-0.09	-0.11	1.00		
7	Internationalization skills	0.38*	-0.00	0.24*	0.44*	0.31*	-0.05	1.00	
8	Sales skills	0.09	-0.01	0.10	0.24*	0.02	-0.22*	0.30*	1.00
9	Econ. principles skills	0.31*	0.13	0.22*	0.37*	0.13	0.13	0.29*	0.24*

* p<0.05

Annex B

Diagnostic	Description	Export		
Model		**1**	**2**	**3**
Detecting unusual and influential data	Residuals, leverage, Cook's D and DFBETA, etc.	Checked	Checked	Checked
Test for normality of residuals	Inter-quartile range (iqr) test and Shapiro-Wilk test	iqr test: 7 outliers Shapiro-Wilk test: z: 4.156 p-value: 0.00	iqr test: 5 outliers Shapiro-Wilk test: z: 4.221 p-value: 0.00	iqr test:7 outliers Shapiro-Wilk test: z: 6.195 p-value: 0.00
Test for hetero-scedasticity of residual	(1) White's test; (2) Breusch-Pagan test	(1) chi^2: 56.17 p-value: 0.0173 (2) chi^2: 8.35 p-value: 0.0039	(1) chi^2: 38.64 p-value: 0.0002 (2) chi^2: 13.19 p-value: 0.0003	chi^2: 87.97 p-value: 0.0615 chi^2: 12.21 p-value: 0.0005
Test for multicollinearity	Variance inflation factor	Mean VIF: 1.53	Mean VIF: 1.14	Mean VIF: 1.55
Test for model specification error	ovtest	F: 0.13 p-value: 0.9427	F: 0.30 p-value: 0.8231	F: 0.56 p-value: 0.6437

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Peer Assessment in Architecture Education

Mafalda Teixeira De Sampayo,

Lisbon University Institute, Lisbon, Portugal, mgts@iscte.pt

David Sousa-Rodrigues,
Cristian Jimenez-Romero and Jeffrey Johnson

The Open University, Milton Keynes,
United Kingdom, david.rodrigues@open.ac.uk

Abstract

The role of peer assessment in education has become of particular interest in recent years, mainly because of its potential benefits in improving student's learning. It also presents benefits in time management by allowing teachers and tutors to use their time more efficiently to get the results of student's assessments quicker. Peer assessment is also relevant in the context of distance learning and massive open online courses (MOOCs).

The discipline of architecture is dominated by an artistic language that has its own way of being discussed and applied. The architecture project analysis and critique goes beyond the technical components and programme requirements that need to be fulfilled. Dominating the architecture language is an essential tool in the architect's toolbox. In this context peer assessment activities help prospective architects to develop skills early during their undergraduate education.

In this work we show how peer assessment acts as a formative activity in architecture teaching. Peer assessment leads the students to develop critical and higher order thinking processes that are fundamental for the analysis of architecture projects. The applicability of this strategy to massive open online education systems has to be considered as the heterogeneous and unsupervised environment requires confidence in the usefulness of this approach. To study this we designed a local experiment to investigate the role of peer assessment in architecture teaching.

This experiment showed that students reacted positively to the peer assessment exercise and looked forward to participating when it was announced. Previously to the assessment students felt engaged by the responsibility of marking their colleagues. Subsequently to the first iteration of the peer assessment, professors registered that students used elements of the qualitative assessment in their architecture discourse, and tried to answer the criticisms pointed to their projects by their colleagues. This led their work in directions some hadn't considered before.'

The marks awarded by the students are in good agreement with the final scores awarded by the professors. Only in 11 % of the cases the average score of the peer assessment differed more than 10 % from marks given by the professors. It was also observed that the professor's marks where slightly higher than the average of the peer marking. No correlation was observed between the marks given by a student as marker and the final score given to that student by the professors.

The data produced in this experiment shows peer assessment as a feedback mechanism in the construction of a critical thought process and in the development of an architectural discourse. Also it shows that students tend to mark their colleagues with great accuracy. Both of these results are of great importance for possible application of peer assessment strategies to massive open online courses and distance education.

Keywords

Education, MOOC, Architecture, Peer Assessment, Marking

1. Introduction

The role of peer assessment in education has become of particular interest in recent years, mainly because of its potential benefits in improving student's learning [1] and benefits in time management by allowing teachers and tutors to use their time more efficiently to get the results of student's assessments quicker [2]. Peer assessment has also relevant in the context of distance learning and massive open online courses (MOOCs) [3]. These education systems have scalability problems in the cost of evaluating students and new strategies are being researched to lower the cost of evaluating many students. In this context peer assessment is very important because it is scalable. For each new student we get one new marker for the system and efforts are being made to differentiate between good and poor markers [4]. Although these efforts are oriented towards objective learning subjects, peer assessment can also be applied in the context of subjective fields, like architecture, painting or music, where it has an intrinsic pedagogic value as a formative activity.

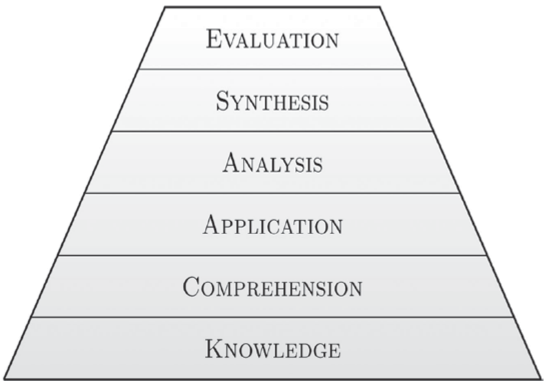

Figure 1: Bloom's taxonomy six levels of the cognitive domain.

The discipline of architecture is dominated by an artistic language that has its own way of being discussed and applied. The architecture project analysis and critique goes beyond the technical components and programme requirements that need to be fulfilled. Dominating the architecture language is an essential tool in the architect't toolbox. The establishment of a method of 'doing architecture' in the student's early learning years is a slow process. It is impossible to reduce the architecture practice to one dimensional aspect and therefore it is of upmost importance for students to develop a critical thinking process about the architecture design process [5]. In this context peer assessment activities can help them develop skills early in their undergraduate education.

In this work we show how peer assessment acts as a formative activity in architecture teaching. Peer assessment leads the students to develop critical and higher order thinking processes that are fundamental for the analysis of architecture projects [2, 6]. The applicability of this strategy to massive open online education systems has to be considered as the heterogeneous and unsupervised environment requires confidence in the usefulness of this approach. To study this we designed a local experiment to investigate the role of peer experiment in architecture teaching.

The method used in the peer assessment experiment aims help student to develop their higher order cognitive skills as defined by Bloom's taxonomy [7, 6, 8]. Bloom identified six levels within the cognitive domain. The six levels (see figure 1) of the cognitive domain[1] characterise fundamental questions that educators have in relation to the learning objectives set for students. This experiment potentiates the development of the the highest order levels of *analysis, synthesis*, and *evaluation* in the students. Analysis refers to the ability to break down material into its component parts, the ability of the student to look at an architecture project and be able to identify the main components of the project that are relevant. Synthesis is associated with the ability to establish a discourse about the project, the ability to have an architecture vocabulary that allows the student to produce communication about the architectural object being analysed. Evaluation is concerned with the ability to judge the value of the material for a given purpose. These judgements are defined against architectural criteria and this learning outcome is the highest in the cognitive hierarchy because it contains elements of all levels (including the lower levels knowledge, comprehension, and application).

In the context of massive open online courses (MOOC) the assessment made by paid staff is prohibitively high and other ways of assessing students achievements has to be derived. Typically the assessment is made by using multiple choice questions, computer assisted marking or peer marking.

It is this final aspect of peer marking that is of particular interest, because it makes the task "evaluation" scalable because each new student that enters the system is also a marker for the system. The downfall of this approach is that not all students are equivalent markers. The same way they will not learn the subjects with the same speed, they won't be able to mark others with the same level of competence and accuracy exhibited by a professional marker. Our experiment shows that this difficulty can be solved by collective action in the form of peer assessment.

The experiment described here was setup to test the premise that any two good markers will show a marking behaviour that is consistent over time and that two bad markers will present uncorrelated marking behaviours. Our hypothesis is that based on these premisses, one can identify different quality markers.

1 Bloom also defined an affective domain and a psychomotor domain in his classification [7]

2. Methods

In our experiment we have 45 students from two professors of the architecture programme of the Lisbon University Institute. The two classes belong to the course *Architecture IV* (4^{th} semester in the undergraduate programme). This course is mainly practical with classes taking place in a simulated architecture office environment.

The peer assessment activities were made during two distinct time periods. The first peer assessment session was held midway the semester and the marking occurred only among classmates. The second peer assessment activity occurred at the end of semester simultaneously with the student's final examination. This time students assessed each other's work irrespective of their class. In both phases each student assessed three other randomly chosen students.

The assessment was divided in a qualitative part and a quantitative mark. Each student was asked to identify the positive aspects of the assessed project and also to identify its flaws and future improvements. They also marked the overall project with a score based on the achievements of the project against the programme of the exercise proposed for the semester.

The first assessment was done in the classroom during a 3h period during which the students were given a slip of paper to fill (depicted in figure 2). They had to fill the slip of paper with both qualitative and quantitative assessment about the project.

A marking guide was distributed (see supplementary material) were students where reminded of the education objectives that were expected at that phase of the semester (the first phase was held on the 6^{th} week of a 12 week course). The students were informed to only consider the aspects mentioned in the marking guide and the materials presented by their colleagues for assessment and to disregard any previous experience and interactions they might have had with that project and its authors. This was very important as classes are conducted in a simulation of a architecture studio and it is normal for students to share ideas, discuss projects and solutions. In the peer assessment exercise it was asked that students disregarded any previous information about the projects they were analysing.

The second phase of the peer assessment was conducted in a similar setting with the exception that it occurred at the end of the semester during the public presentations of their work to a jury. This jury was formed by the two professors of architecture and by an external invited member (usually a professional architect). This public examination occurred over two days and the students were asked to do the peer assessment based on their colleagues presentations.

<table>
<tr><td>PROJECT ID</td><td>POSITIVE ASPECTS</td><td rowspan="2">MARK (0-100)</td></tr>
<tr><td>MARKER ID</td><td>ASPECTS TO IMPROVE</td></tr>
</table>

Figure 2: Slip of paper used in the Peer Assessment

3. Results

This experiment showed that students reacted positively to the peer assessment exercise and looked forward to participating when it was announced. Previously to the assessment students felt engaged by the responsibility of marking their colleagues. Subsequently to the first iteration of the peer assessment, professors registered that students used elements of the qualitative assessment in their architecture discourse, and tried to answer the criticisms pointed to their projects by their colleagues. This led their work in directions some hadn't consider before.

The quality of the peer assessment process was very high and through textual inspection of the student's answers the professors concluded that the limited space available for the qualitative aspects forced students to synthesise and develop a critical thought process. Globally the comments made by the students were very assertive, but in some cases they showed that some students still didn't possess an architecture discourse capable of communicating in architecture language. The peer assessment was very useful in identifying such cases.

The quantitative marks awarded by the students in the second peer marking period are in good agreement with the final scores awarded by the professors. Internal consistency between the marks assigned by the different students was high. In a 100 point scale the spread of the marks was low in the majority of the cases as shown in figure 3. Only in one case the marks varied 40 points while the majority showed less than 20 point of variation.

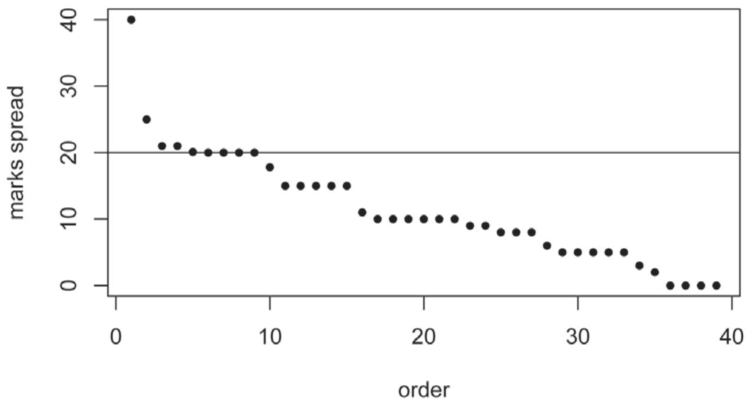

Figure 3: Marks spread, ordered from highest spread to lowest spread (in a 100pt scale).

The observation that the marks spread was low allowed us to compute a simple arithmetic average of the marks without incurring in great errors or needing advanced schemes for computing a score from the individual marks.

Alternatives to the simple average would include the removal of marks that diverged from the average more than a fixed threshold or considering a weighted computation based on other information like students previous reputation. The latter option would require an iterative marking process that we didn't have in this experiment while the former would not be fully useful in this scenario as the number of marks per student was low (on average each student marked another three students work) making the outlier detection difficult, if not impossible.

Only in 5 cases the average score of the peer assessment differed more than 10 % from marks given by the professors (students outside the range [–2,+2] in figure 4). This represents less than 12 % of the students. It was also observed that the professor's marks where slightly higher than the average of the peer marking. No correlation was observed between the marks given by a student as marker and the final score given to that student by the professors. This seems to imply that a good marker doesn't necessarily need to be a good student, mainly if following a marking guide.

Besides the agreement between the averaged marks and the final mark given by the jury observed in figure 4, we wanted to understand if there was a correlation between the marking activity and the learning activity of the students. Is a good student also a good marker? For this we computed the marker average error by comparing the marks they assigned to those given by the jury and computed the Pearson correlation between this average error and the mark they received as students by the Jury.

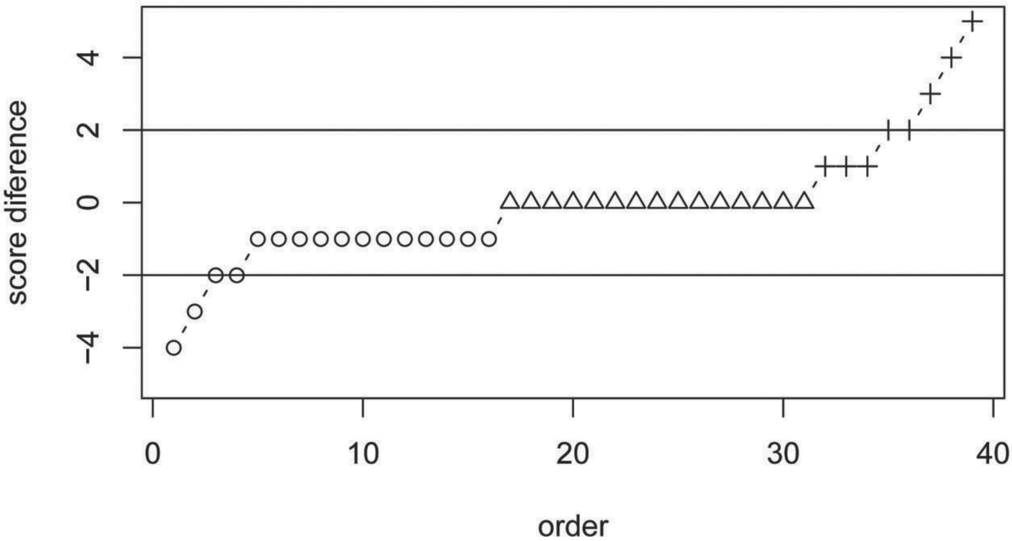

Figure 4: Difference between the average mark and the jury score (in a 20pt scale).

The results show that there is no correlation between the two activities. The Pearson correlation value is –0.063. This lack of correlation is also observed in the plot of the average marker's error against their final mark in figure 5.

This lead us to think that in this particular context, the marking activity and the application of their architectural knowledge isn't yet correlated. While the marking activity was positive correlated with the final marks awarded by the jury, with a Pearson correlation of +0.65, meaning that student were able to analyse and criticise other student's work, this ability was not directly correlated with their own work performance as if the application of the concepts they used while evaluating others was not taken fully into consideration in the output of their projects.

We found this result surprising and it highlighted the importance that the peer assessment activity has. It exposes students to aspects of architecture that they know in abstract, but that they failed to consider when are transferring that knowledge into their own work.

By moving the students from the role of the architect to the role of the critic, they become aware of aspects of the architectural process that they didn't consider in their own work. This leads to a reflection process and forces them to try to fix the deficiencies in their architectural practice in subsequent work.

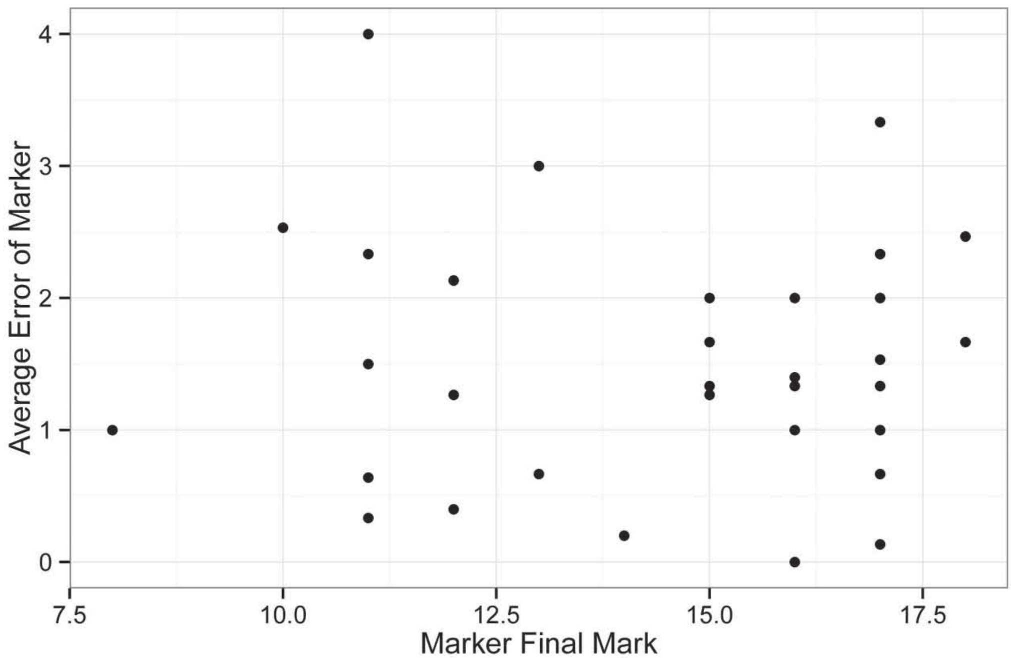

Figure 5: Average marker's error vs. marker final grade (in a 20pt scale).

4. Discussion

In this paper we presented an educative experiment that incorporates peer assessment in the teaching of Architecture to second year undergraduate students. The experiment of peer assessment had a formative aspect to the teaching of the students as it allowed the development of a critical thinking process about other students projects.

This activity presents itself as a very interesting way to tackle some pedagogic objectives, namely those that are usually in the top of Bloom's taxonomy and require the higher cognitive skills of *analysis, synthesis,* and *evaluation*. The exercise allowed students to engage in high level thinking about architecture project. It was observed in class that students incorporated aspects of the languages used during the experiment in their architectural discourse. Also, the students employed elements and suggestions from their colleagues into their respective work, meaning that the peer assessment worked clearly as a feedback mechanism for students. This has the main advantage of relieving the task of giving feedback on their progress exclusively from the professor(s) of the discipline, allowing for more feedback points during the semester.

These observations prove the usefulness of the peer assessment strategy as a formative tool. The data produced in this experiment shows peer assessment as a feedback mechanism in the construction of a critical thought process and in the development of an architecture discourse and language.

The quantitative aspect of this experiment shows a correlation between the marks given by a student and the final mark given by an expert panel (professors, professionals). Students tend to mark their colleagues with great rigour. This is a very important conclusion because it is of great importance for possible applications of these strategies to massive online courses and distance education.

The application of peer marking to massive online education poses many problems but the tool can be used for aspects of the formative process besides the attribution of a final mark. In this experiment we showed that the marking was in agreement with the final expert mark. This is good indicator for future experiments in larger scales. The success of this experiment can be attributed to the controlled environment and the engagement of the students. The task of doing peer assessment was considered by the students to be fun. In a online course people might not be engaged all at the same level. Their starting baseline might be more heterogeneous than in traditional courses. They might drop off and not do their assigned assessments, or just rush over the assessment to get it done. These kinds of problems need to be tackled if the next iteration of this work in order to apply peer assessment to massive online courses. In any case there are already strategies of identifying good markers and bad markers by using iterative peer assessment schema [4] and it is our objective to explore these results in the development of future education systems.

Acknowledgments

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Assessment guide

(Translated from the original version in Portuguese)

Architecture IV

As defined in the by the curriculum of Architecture IV with respect to the learning objectives of this teaching unit, architecture is defined as an experimental activity, where the project is a moment of synthesis that integrates many factors – context, idea, form, function, scale, language. The project is based on the development of concepts through drawings and models (its main interments) in the realm of the creative process.

The teaching methodologies privilege a practical approach to the learning process where students are incentivated to use varied means of representation, both as research tools and as communication support.

In this methodologies it is incentivated the argumentation ability of students about the options taken by them in the execution of their work and the ability to argue about the qualities of other students work. This aims the development and consolidation of the students critical thinking in interpreting the location and the quality of the proposed spaces.

It is proposed to the students that they do a critical evaluation (both qualitative and quantitative) of their students colleagues.

The evaluation must take into consideration the following factors:

1. The student knows the content of the exercise of this course and must ponder what is asked in this guide (including the elements that the students are expected to submit at this phase).
2. The final evaluation of the student (as marker) is weighted by his critical thinking ability.
3. The student must only assess the result of the project and not its development.
4. The student (as marker) must not communicate with the colleague author of the marked project during the assessment (can not make questions about the project).

At the end of the exercise each student will receive the feedback with his/her colleagues assessments.

The Paradigm Change in STEM Education – Has It Happened Already?

Jan Slovák

Department of Mathematics and Statistics, Masaryk University
Kotlářská 2, 611 37 Brno, Czech Republic
e-mail: slovak@muni.cz

Abstract.

This short paper aims at collecting observations and thoughts related to the Education in Science, Technology, Engineering, and Mathematics (the so called STEM). In this way we would like to initiate new studies and experiments. In particular, we shall question how the current trends of the massified Education, together with the available technologies and the changes in the attitudes of the new generations of both students and teachers, are reflected in the attitudes, knowledge and skills of the graduates. The method of the paper consists of comparison of well-known general facts and conclusions with the author's own experience in teaching Mathematics. Particular attention is devoted to the (mis)use of new technologies in these areas.

1. Introduction

Over centuries, the main content of teaching and learning swapped repeatedly, roughly speaking, between two main phases: 'teaching facts' and 'engaging the intellect'. These are the two basic approaches to Education and both can be done in a useful and practical way, or the opposite. Actually, another point of view is that these are rather two parts of the same process and it could be only a matter of taste or presentation, whether we focus more on the 'teaching facts' or the 'engaging intellect' part. But definitely, the tendency to stress the first or the latter one swaps in time.

In recent decades, the tendency to teach facts was perhaps stronger than ever before. Moreover, there were many further risk factors appearing in parallel – too much specialisation, fit for purpose training, unrealistic expectation from new web based technologies, etc.

Long back, the Education used to be very *individual*. There were only a few students, all living together with their teachers at colleges, and the entire Education was based on individual learning, and public disputes and discussions with fellows and teachers. Education was very *international* at those days too (linked rather to some religion/church than states or regions).

The current massive education platforms are mostly just the opposite – often very regional and very anonymous. At the same time, the knowledge seems to be available everywhere and for free at the internet, while the usage of all the engineering and information technology inventions seems to be easy without knowing the principles why and how they work.

All these circumstances lead to the belief that the Teaching Facts Paradigm seems to be:

- practical (the students perform tasks fast);
- efficient (the students immediately display the 'right' knowledge);
- manageable (even in massified forms of Education);
- easily supported by technologies (accessible even in online and distance education versions).

No wonder that this has been the dominant approach over decades and gets much support now. But how and why should we engage the intellect then? We should think on the following points:

- learning vs. *understanding;*
- memorizing vs. *thinking and deducting;*
- blindly applying vs. *developing and experimenting;*
- watching vs. *discovering.*

All this is hard to achieve in the massified Education forms, and it is linked to the general problem of perception of information.

2. Impact of personal typologies in Education

In a face to face contact, good teachers always pass their ‘experience and opinion’. This is perhaps the best way to help the students to understand the topics really. Unfortunately, this mostly fails with big groups.

One of the reasons is that typology of the individual people varies, which is usually balanced well in the face to face contact (at least in the presence of reasonable social intelligence). But unfortunately, there cannot be a universal method for lecturing in large classes since we cannot address all the types of personalities in parallel. The way out seems to be to invoke thinking and communication among the students, initialised, supervised and amended by the teachers. This is exactly the point where smart usage of new technologies together with relevant changes in the structure of instructions, workgroups and individualised learning should help.

So what is special about the perception during the learning? Perhaps every teacher has noticed that some people need ‘intuition’ first and only then they can perceive the ‘technicalities’, though most of the population needs the opposite.
Such questions were addressed by Jung’s typology of personalities, and it is remarkable that these obvious facts heavily used in the Human Resource management were given little notices in Education management and practice. There is a rather simplistic version of such typology known as Myers-Briggs Type Indicators, used heavily by HR people nowadays, see [1]. Here the type is based on four dichotomies:

- the attitudes are *Extraversion* (E) versus *Introversion* (I)
- the perception functions are *Sensing* (S) versus *Intuition* (N)
- the judging functions are *Thinking* (T) versus *Feeling* (F)
- the lifestyle is *Judging* (J) versus *Perception* (P)

This provides 16 types of personalities, for example ENTJ, ISTJ, etc.

A lot of criticism applies to the MBTI tests and to the use of the typology in the HR practice, see e.g. [2], pointing out the low re-test reliability (caused perhaps by mechanical splitting of the results in the individual dichotomies at a virtual central value, though most of the population displays results close to this value). But for our aim, this seems to be perfect explanation why any universal effort to teaching in big groups based mainly on the teachers’ presentations has to be dammed to failure.

In my own practice, I have been most interested in the polarized (NT) opposed to (SF) subgroups of students (or teachers). The members of the first group heavily need `intuition’ first, they want to think on the general picture, on the reasons why to deal exactly with the discussed phenomenon etc., and only then they can perceive the 'technicalities' and work on real practical tasks. The people from the (SF) group are just the opposite. Needless to say that there are many more SF's than NT's in the population! We shall return to this point in the realm of my Mathematics courses in a moment.

3. How are the colleges/schools performing?

Next, we come to the obvious question how the colleges should develop their approaches to curricula and the teaching/learning standards. Nearly all studies and statistics say that the outcomes are poor and some of the authors relate this fact with our question raised above: *too much of teaching facts and too little of engaging the intellect.* But we can also rephrase this as a perhaps wrong balance and order of practicing intuition and technicalities. A nice interview with Dr. Jo Handelsman, Howard Hughes Medical Institute Professor in the Department of Molecular, Cellular and Developmental Biology at Yale University, can be found in [3]. Roughly speaking, the students of Biology are getting many fragments of facts in individual sub-disciplines, but they lack both global picture and understanding. She claims that using the conventional science instruction, only 10 to 20 percent of lecture content is actually retained by students, while the professors spend hours explaining to them. Opposed to that, active learning schemes have proven to be more effective, she says.

Actually, there are even much more pessimistic results of recent studies explained in the two books by two sociologists, Richard Arum and Josipa Roksa, [4], [5]. Their first book is based on the study of more than 2300 bachelor students in24 schools of different image claiming that, with a bit of exaggeration, the students learned a lot of bad habits while their critical thinking and readiness to work got often even worse. In the second book they extend the study to the general changes in the social behaviour in the last 40 years. Their observations include:

- earlier, rather introvert people having their behaviour and values copied from their teachers and parents were admired as wise and serious;
- now, the immediate response from the colleagues is the guiding principle and the extrovert people with no values of their own are winning;
- university teachers are too much under pressure of student evaluations and their standards have developed in similar way too, and thus, the students have never had studied as little with as good marks as nowadays.

Although their study is criticised for using exclusively the Collegiate Learning Assessment (CLA) Performance Task to test the outcomes, which is not believed to cover all the abilities to be tested, their results match very well the lack of the 'engaging the intellect' part of the educational process, combined with further sociological data.

Let us pose another provoking question. Can the students and teachers mutually understand each other? We could guess from other studies that, at least, this will not be easy. As shown in the *Generation Z survey,* the current teenagers are, unlike their teachers:

- multitasking across 5 screens;
- keeping attention for less than 8 seconds only;
- collaborate better, but more than 10 % of them suffer hyperactivity and further neurological deviations;
- live in virtual realities.

4. Do the new technologies help?

In the last decade we have witnessed the very wide use of the web based technologies:

- more communication and working in groups in diverse e-learning collaborative tools (or just using general tools like Skype, Hangouts, etc.);
- easy capture of lectures;
- sophisticated on-line learning schemes provided on large public platforms (Moodle or BB platforms, all the MOOC's etc.);
- virtual web based universities (and virtual diplomas).

All this burst of ideas, approaches and tools has got many good flavours. Watching the popularity rankings of the tools and platforms on the web, we learn about Adobe Connect, Blackboard, Canvas, Coursera, edX, ePals, FaceTime, iTunes U, Moodle, Schoology, but also Google Plus Hangouts, Skype, YouTube and many more general purpose communication platforms. Some of them are used internally at schools, some of them provide free public service for everybody.

There are many questions in place here. Does this all always lead to real learning? Which part of the crowd does it support best – the average, the best ones, or the laziest and weakest ones? Does the technology strengthen the 'teaching facts' or the 'engaging intellect' parts? Does it help to balance them right for the different types of personalities? And the most appealing question – will regional universities need their own real teachers at all?

The answer to the latter question is, of course, yes and the reason is the same as with theatres and musicians/actors. Although there are all the recordings of the absolutely best ones, still the people enjoy real live concerts. Simply, they want to experience the emotions, experience, and passion live, and the same applies to teaching. Let us add a few further observations suggesting some partial answers:

- movies are good for initiating interest and more, but it is difficult and extremely labour-intensive to make them to provoke critical thinking;
- thinking goes better with still images, schemes or texts which is typical in STEM, but also in Medicine etc.;
- the right technology should allow for 'live' appearance of teachers/speakers combined with classical slides displaying the topic to be discussed – this very much imitates the standard way of consulting in someone's office;
- the technology should invoke symmetric discussion the same way in any kind of groups;
- the technology should allow the teacher to create the messages/lectures easily, in order to keep the feeling of rather real time discussion than a perfect anonymous performance;

All this can hardly work just with videos from the classrooms or some universal MOOC presentations, as we mostly know them.

5. Mathematics and STEM

All the questions raised above are particularly urgent within the STEM programmes. Moreover, there are the following observations to make:

- the individual components (Science & Technology & Engineering & Mathematics) should not be taught separately, rather we should like to build a global picture;
- the 'understanding' part of the process is the more important one, while mere memorizing of facts can be even dangerous;
- it is extremely hard to manage the STEM education in big crowds due to various perception schemes (and abilities) of the individual students;
- the technologies can be very helpful here, but they also can spoil the game completely.

Mathematics is a quite specific part of the STEM which could be understood as the common language or one of the possible approaches. Unfortunately, this often is not the way how it is presented. Mathematics should help to the 'engage intellect' part of process. I am intensively teaching Mathematics for big classes of Informatics students and my own experience says that the videos with lectures or further similar material are very appreciated by the students, but they do not help much to their real understanding. Rather, their existence is often misleading them in the belief that they will be able to browse through the videos before the exams like they watch the sitcoms. Just the really serious students use them the right way, coming back to unclear points when revisiting or filling gaps later.

Thus, I was rather seeking for a structure of the teaching process and the exploited support technology which would allow for a combination of the following parts:

- a flipped-classroom approach based on up to date prepared presentations amending the practical aspects of the lectures, available to the students short before the main lectures;
- standard lectures (in the rather classical big lecture hall standard, coming with usual tutorials in smaller groups) combining the practical use of the mathematical tools with rather intuitive explanation of the methods and procedures;
- practical seminars devoted to the numerical and computational aspects (computer based activity in small groups with a tutor);
- individual problem solving (perhaps in small groups, invoking mutual discussion between students).

In general, there are many ways how to teach Mathematics. Mostly, the instructors try to do *everything completely 'right'* (from the pure Mathematics point of view) and they believe, one day the students will themselves understand how beautiful and useful the Mathematics is. The other possibility is to *focus on the 'right things'* and to present them as useful tools and we hope that the best students will come to understanding of the tiny details too, while the average students will at least remember the usefulness of Mathematics.

Another point is the overall structure of the exposition. Usually the instructors try to provide 'complete' exposition of the phenomena the first time already. But this makes it nearly impossible to gain complete understanding. The other approach is touching topics in a *simple way first* and 'coming back' with new understanding later again.
Perhaps, we should like to specify what we mean by Mathematics first. Since Mathematics became also the name of one of the subjects taught at Grammar School level, the people obviously think that they have met Mathematics, they have perhaps hated it, and they believe Mathematics is just playing with numbers or, even worse, the abstract letters representing them. The etymology of the word Mathematics displays a quite different picture. The Online Etymology Dictionary reveals (abridged):

mathematic (n.) late 14c. as singular noun, replaced by early 17c. by mathematics, from Latin mathematica (plural), from Greek mathematike tekhne "mathematical science," … from mathema (genitive mathematos) "science, knowledge, mathematical knowledge; a lesson," literally "that which is learnt;" related to manthanein "to learn," … (cognates: Greek menthere "to care," Lithuanian mandras "wide-awake," Old Church Slavonic madru "wise, sage," Gothic mundonsis "to look at," German munter "awake, lively"). As an adjective, 1540s, from French mathématique or directly from Latin mathematicus.

The etymology itself suggests that Mathematics should be following rather the questions of "WHY" then those of "HOW" and it should be rather understood as many diverse ways of consistent thinking.

So why do people remember Mathematics so much differently, even those very knowledgeable ones? For example, J. W. Goethe said *"Mathematicians are like Frenchmen:*

whatever you say to them they translate into their own language and forthwith it is something entirely different"; or St. Augustine wrote in his book (De Genesi ad Litteram, Book II, xviii, 37) *"The good Christian should beware of mathematicians and all those who make empty prophecies. The danger already exists that mathematicians have made a covenant with the devil to darken the spirit and confine man in the bonds of Hell."*; even worse, M. Luther wrote *"Medicine makes people ill, mathematics make them sad and theology makes them sinful.'"*

6. The "Brisk Guide to Mathematics" project

Following the wish of the Faculty of Informatics management at the Masaryk University in 2004, I took up the challenge to reshape the Mathematics instruction for the entire faculty.
My initial strategy was:

- to focus on practical topics with easy going intuition and rather simple algorithms (and be aware that the intuition is too difficult to perceive without any knowledge);
- to work in spirals, i.e. to come back to the topics with a better supply of tools and more tasks to be solved (and be aware that this might also lead to "spirals of misunderstadings");
- to experiment with the format of the lecturing in order to match as many types of personalities as possible.

The immediate consequences included:

- we are building discrete models first, the continuous analysis comes later to deal with convergence and robustness;
- we avoid splitting Mathematics into Algebra, Analysis etc.;
- we use innovative technology to invoke the thinking part of the process and to activate the students.

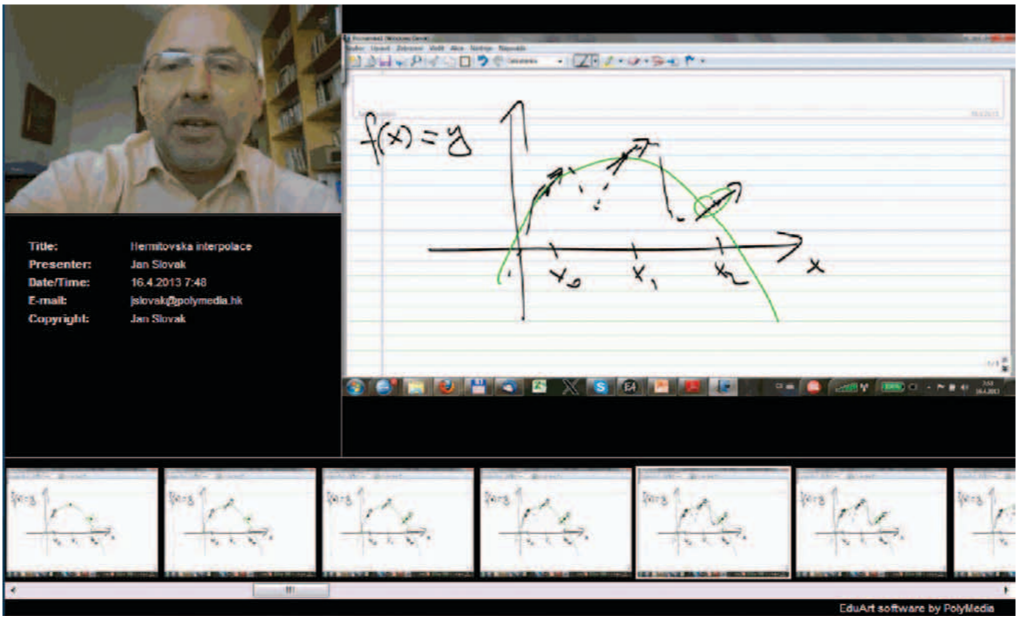
All this is following the main goals of the four semester long course:

- the students should be able to formulate precise definitions of basic concepts and to prove simple mathematical results;
- the students should perceive and understand the meaning of roughly formulated properties, relations and outlooks for exploring mathematical tools;
- the student should master tools and algorithms behind mathematical models and they should appreciate their usage.

Given the time frame and the available formats of the instruction, these goals are ambitious and they require a very rough and active approach. The students have to find their own paths and they should be enforced to do so.

With a wider team of collaborators, we have prepared the unconventional textbook underlying this course which we have called 'Brisk Guide to Mathematics' and we hope this book should also help to push the students to their own paths. The book is printed in two columns which are rather independent of each other, one focused exclusively on practical tasks and examples, while the other column provides a complete exposition of theory and usage of the individual concepts and tools. Moreover, the theoretical column is very inhomogeneous in both the details and the complexity of the exposition and the readers should be self-navigated by the so-called emoticons acting as switches between the characters of the individual blocks of text. The electronic version of the Czech book is available at http://www.math.muni.cz/Matematika_drsne_svizne.html and we are working on the English version now.

The instruction itself has been supported by software tools allowing for easy capturing of any presentation, based on the full resolution slides (as they appear on the screen) combined with a full audio-video recording of the speaker. The result is an open format html5 web presentation available freely on all platforms.



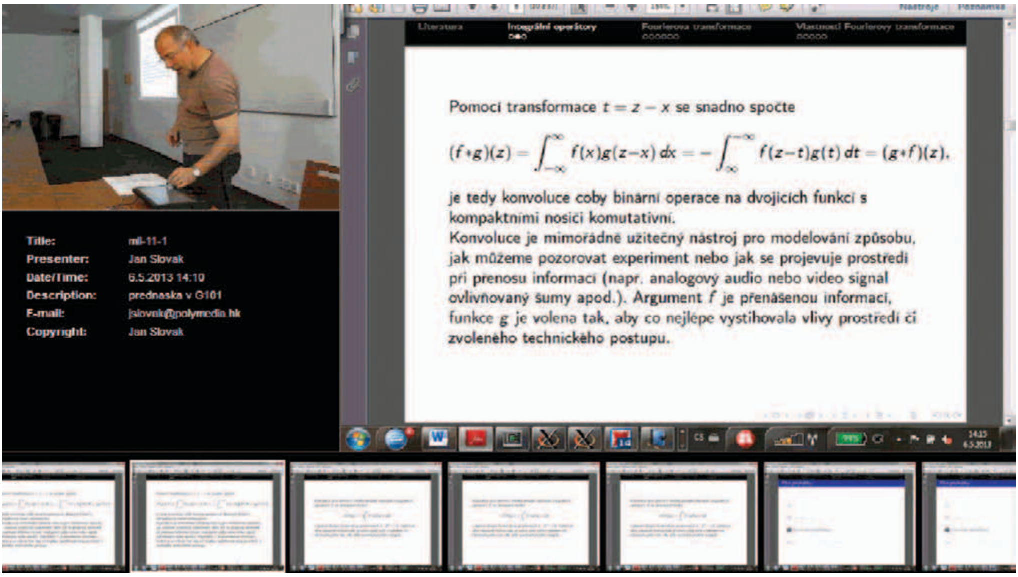
The screen-shot above illustrates one of the practical presentations prepared before the main lectures and displaying the main algorithms and tools to be discussed soon. These presentations are available[1] to the students a few days in advance, so that the people who

1 I have been using the software EduArt™ developed and distributed by Polymedia Technologies, see www.polymedia.cz for more details.

need the practice first can watch them in time. Indeed, the students have reported the extreme usefulness of such presentations before the lectures (perhaps the "SF" subgroup of types, in particular).

Next, the theoretical lectures are presented and their recording by means of the same technology is available to students too, followed by regular tutorials. This is usually followed by wide discussion on the individual practical problems supported by the general e-learning platform provided by the university.

In general, the exploited technology allows for completely symmetric mutual communication combining audio-video and slides, which is very lean and effective, since the slides remain in their jpg format full resolution all the time and thus the data flow of the presentation is very low. Unfortunately, the university has not acquired a multilicense for this technology solution and so this form of communication is not yet widely spread.



The experimental teaching within the "Brisk Guide to Mathematics" project has got the graduates for several years already and the responses are diverse, quite as expected.

Clearly the new model of structuring and presenting Mathematics teaching is more than welcome by the best students. We have not got a detailed statistics, but the general university questionnaires reflecting the opinions and feelings of students suggest at least those in the 1st quartile of students by their results of study find the model very good (at Masaryk University we are still strict with having about 1/3 drop rate in Mathematics in general, and the 'A' or 'B' marks are rather exceptional). Also their skills seem to be very good, while the average students (or those less motivated ones) have not got worse. This was exactly my main goal.

In general, it seems that the existence of the practical presentations (closely related to the main lectures and tutorials in both topics and time) and the recordings of the lectures, together with the consequent returning to topics in spirals and with different complexity of the parts of the exposition, help to find the individual paths for each student. Some of them might come back to the practical parts after they enjoyed the theoretical lectures (the NT subgroup), others enjoy the practical presentations before the lectures already (the SF subgroup) and all of them can gain a lot from the mutual discussions among the students themselves.

There are two typical complaints. The first one is pointing out the lack of explicit lists of detailed simple tasks to be mastered in order to pass. This is exactly what the students are often used to in other courses, cf. the comments in section 3 above. The students also complain about a too wide scope of the course making it too difficult and demanding.

The students report positively on the unconventional use of the technologies and would like to see it spread more widely across the faculty.

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[5] Arum, R., Roksa, J., Aspiring Adults Adrift: Tentative Transitions of College Graduates, Chicago: University of Chicago Press, 2014.

[6] Generation Z survey, Sparks & Honey, USA, April 2014 (< 18, compared to 20–30 and elder).

The Science and Technology Commercialization, Financing, Cooperation and Empirical Analysis

Dariusz M. Trzmielak

University of Lodz

Abstract

In this paper, we empirically study the key elements affecting commercialization stages and process. Based on through analysis of empirical study, the author indicates the important issues influencing on the new technology development within three market segments: scientists, business and organization developing ideas and businesses. The data from a survey study of 670 respondents in 42 countries is used to analyse the significant determinants increasing managerial interest in commercialization.

Key words

commercialization and managements

Introduction

Many studies have identified commercialization as being significant activity of success organization. High-tech markets have different actors, regulations, the sources of ideas and organization development, research projects and businesses. The main goal of this article addresses the following key question: How do the external and internal factors stimulate the technology commercialization? This paper includes also answers to some other questions such as: How do organization cooperate and recognize key elements of new technology development? How do representatives of the different countries classify the importance of the high education level of scientists, the strong leader in the commercialization team, the high level of the entrepreneurial culture, the strong relationship between business and academia, active regional innovation policy, the strong position of organization developing ideas and business, easy access to private and public financial sources and the access to wide range of financial sources.

The first section of the presentation shows a theoretical analysis concerning business and scientists factors that focus on the development of ideas as well as businesses' preferences as to the opportunity of the new technology developments on the world's markets.

The second part focus on methodology employed by author in market research project the European Union Member States, US, Canada and other countries. Third and fourth sections describe the fundamental factors affecting the commercialization of patents, know-how and scientific research results. The paper is based on the online opinions and suggestions given by the representatives of: national and international capital, micro, small and medium sized and big enterprises, private and public institutes, incubators, innovation centers, technology transfer centers, research and development centers, research parks, science and technology parks and universities. The factors involved in the description include: the differences between science, industry and business development organizations concerning the relation quality of academic and business organizations capable of being involved in the new technology development process, the position of different organizations on the market, the level of education, the activity of regional innovation policy, the public and private financing of new technology development.

In the final part, further investigations concentrate on consumption of funding from business angels, cooperation with scientific environment in seven selected regions, and in the segments declaring different innovative activities in the market or in the organization. Multidimensional scaling was used to conduct the above analysis. The MDS map was created to position the surveyed regions: USA and Canada, Asia, South America, Australia and New Zealand, countries from so called "old" European Union, countries from so called "new" European Union (excluding Poland), Poland, other European countries and Israel, and remaining surveyed countries, according to the level of consumption of business angel funds and cooperation of business with academia[1].

Significance And Context

As the world economy continues to develop, a number of economies are emerging as major opportunities for new investment. China, India, Central and East Europe, South Korea and Brazil are strategic markets representing important sources of new growth, and they are rapidly becoming major players in the new global technology ecosystem. Prahalad[2] also seems to share the vision that the increasing pace of technological innovation and the growing affluence of ***emerging*** economies are the future global trend.

Entering international markets by firms from emerging economies also means entering the arena of global forces affecting business in many ways. Globalization refers to the process of increasing social and cultural inter-connectedness, political interdependence and economic, financial and market integration[3]. In the past two decades globalization has brought about dramatic changes in business around the world. The effects of globalization cited in the literature can be summarized as global market opportunities and global market threats[4]. The global market opportunities refer to the increase in market potential, trade and investment potential, and resource accessibility[5]. Such opportunities enable firms to access international markets for resources and customers due to trade liberalization, advances in telecommunication technologies, biotechnologies, the internet, and a worldwide convergence of customer demand. The knowledge and technology commercialization is stimulated by:

- the increase in market potential,
- the increase in trade and logistics potential,
- the increase in investment potential,
- the increase in accessibility of resources: finance, R&D, human capital, networks.

1 Przygotowanie części artykułu zostało sfinansowany ze środków Narodowego Centrum Nauki przyznanych na podstawie decyzji numer DEC-2011/01/B/HS4/05200" – The part of article has been prepared based on Polish National Scientific Agency project – DEC-2011/01/B/HS4/05200.

2 C. K. Prahalad, Learning to Lead, "Wikalpa" 2005, Vol. 30 (2), p. 1–9.

3 Giddens A. The consequences of Modernity, Palo Alto, Stanford University Press 1990 and W. Molle, Globalization, Regionalism, and Labour Markets: Should we Recast the Foundations of the EU Regime in Matters of Regional (Rural and Urban) Development?, *"Regional Studies"* 2002, Vol. 3 (2), p. 161–172.

4 S. Fawcett, D. Closs, Coordinated Global Manufacturing, The Logistics/ Manufacturing Interaction and Firm Performance, "Journal of Business Logistics" 1993, Vol. 14 (1), p. 1–25.

5 Levitt T. (1983) Globalization of Markets, *"Harvard Business Review"* 1983, Vol. 61, p. 92–102.

On the contrary, the commercialization is defected by the obstacles seen as[6]:

- higher uncertainty caused by vanishing old barriers and emerging new barriers (culture, institutions like IP protection),
- intensified competition,
- increased demand uncertainty.

Achievement of maintainable competitiveness on a global scale by the European Union will require a dynamically developing economy based on knowledge. The development of research and new technologies have become a basic element of European Union strategy (Lisbon Strategy). The initiative to create a common European Research Area (ERA) brought about an acceleration in integration. The creation of common technologies and their development have become a priority in research programs such as, for example, framework programs.

Research and Development (R&D) expenditure in Europe remains at a level of 2,03 % of GNP, which is lower than in the USA (2.87 %), South Korea (4 %) and Japan (3.36 %) and higher than (1,7). China[7]. The European goals in research and development, as set by the Lisbon Strategy, are to achieve by 2020 R&D intensity of at least 3 %. In 2005, only three Member States exceeded the European Union goal of achieving R&D intensity of 3 % of GDP: Sweden, Denmark and Finland. The average European Union member R&D intensity is lower than in United States[8]. The new members of the European Union have lowered the European Union R&D intensity average because only four countries, namely, Czech Republic, Slovenia, Hungary and Estonia have higher R&D expenditure than 1 %. The majority of countries, including Poland, have R&D intensity below 1 % (Poland had 0,9 – 2012) of GDP that make technology transfer and innovation policy national strategy for the next few years. The phenomenon of Poland's development (as an example of Central and East country) has attracted a great deal of both theoretical and empirical attention in recent years, for many reasons. The first is the growing willingness of firms and academic organizations to engage in R&D. Deloitte report indicates that eight to ten enterprises, which work on R&D project, cooperates with science and research organizations[9]. Secondly, Poland's European Union membership has wide-ranging implications for technology and innovation policy. These factors are viewed as market drivers which need to be examined and understood to help

6 D. Trzmielak, E. Gwarda-Gruszczyńska, M. van Geenhuizen, Technology initiatives, university-industry collaboration in emerging economies: Opportunities and threats in the global market, [in] *Energy and Innovation Structural Change and Policy Implication,* ed. M. van Geenhuizen, W. J. Nuttall, D. V. Gibson, E. M. Oftedal, Purdue University Press, West Lafayette 2011, p. 285–309.

7 Eurostat, Science, technology and innovation in Europe, Pocketbooks, 2013, p. 30.

8 Ibidem, p. 30.

9 Deloitte, Badania i rozwój w Polsce, Raport 2014, Warsaw 2014, p. 15.

the innovative and cooperating organizations in building competitive advantages[10]. Markowski[11] classifies the incentives and barriers of business and science interaction in Poland. Based on that, it can be concluded that on one hand in Poland there is a gap in financing of research and development, but on the other hand there also are a number barriers such as: inadequate laboratory equipment, unwillingness to apply for patents, low level of social capital, lack or low quality level of business support institutions, which all together hamper possible investments.

The R&D programs, addressed to small and medium businesses have particular significance. However, the structural changes in the external environment pushing for a more proactive role of universities in technology transfer started in Europe in the early 1990s[12]. The transfer of technology from academia to commerce is the key to the commercialization of academic research results. Analysing results achieved in Europe and the US, it may be stated that Europe is ahead of the US, Japan and South Korea in terms of licenses and new companies produced, whereas Europe trails US in terms of income from licenses participating in research[13].

The strategic goal of the many governments is to create a competitive economy. One of the fundamental factors affecting this is tough world competition based on innovation. A second major factor is the need for new technology developments. Especially, Central and East economies require acceleration of its growth in high-tech markets and more added value for the small and medium sized enterprises sector. In the real economy, nothing is possible without the resources to compete on the market. Any new venture must have the financial resources to operate on the market and put together the information that investors need if they are expected to provide capital.

Based on the analysis of British market Barker, Gheorghiu and Cameron[14] convince, that private sector investments in research and development are relatively low, compared to the utilization of R&D products for competing on international level. Investing in research and development can be understood as purchase of licenses, patents and

10 D. M. Trzmielak, New Technology Commercialization and Access to Capital – Polish Perspectives and Overview of Research. [in:] *Management of Innovation & Technology.* The 4th IEEE International Conference. Bangkok, Thailand 2008, p. 831–836.

11 T. Markowski, Bariery współpracy na styku nauka-praktyka a rozwój regionalny, [w:] *Partnerstwo dla Innowacji,* ed. B. Piasecki, K. Kubiak, Wydawnictwo SWSPiZ, Łódź 2009, p. 97–104.

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14 K. Barker, L. Gheorghiu, H. Cameron, United Kingom public and collaboration in R&D, [w:] *European Collaboration in research and Development. Business Strategy and Public Policy,* red. Y. Caloghirou, N. S. Vonortas, S. Ioannides, Edward Eldar, 2002, ss. 186–209.

results of research, as well as co-financing of costs incurred by those implementing high-technology projects[15].

Financing of R&D activities undoubtedly strengthens cooperation between organizations. The compensation function of investments in managing futures incomes is very important. Entities cooperate closely to obtain the financing directly, or invest in prospective innovations[16], but cooperation on a technical level, and cooperation of high-tech organizations can be solidified through acquiring knowledge, increasing technological capabilities, and consequently also their competitiveness.[17]

Framework For Survey – Methodology

The empirical part of article is focused on the importance of financial sources in new technology development and cooperation between science and business. A survey has been conducted between 2008–2010 to gather the insights and factors for the development of technology policy and innovation. The data sample size was 670 responses and represents 5 % of the research population. The research population has three levels: countries (listed by World Intellectual Patent Organization as patent applicants at the top 50 offices), organizations and respondents. The online questionnaire was sent to potential respondents in 50 countries (42 countries were finally represented in the analysis). Additionally, since 66 % of the scientists' and businessman's responses represent European Union and were submitted by persons familiar with the organizer of survey, the data may be biased towards organisations and people who may show more interest in the surveyed areas than normal. The results open up a new area of investigation – the preferences for financial sources of capital across the countries in the region.

Generally the survey focuses (research purposes) on the factors that impact on the commercialization of new technology and the methods used for market potential assessment. The data given by respondents constitutes crucial material for comparison of the opinions and activities of three main players on high-tech markets: scientists, high-tech companies and organizations developing ideas, and growing business networks (e.g. science and technology parks, innovation centers, technology transfer centers, high-tech incubators).

15 W. J. Mitchell, Challenges and opportunities for Remote Collaborative Design, [w:] *Collaborative Design and Learning Competences Building for Innovation,* red. J. Bento, J. P. Duarte, M. V. Heitor, W J. Mitchell, Praeger, 2004, p. 4–12.

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One of the area of investigation has been the activity on the financial market.[18] The respondents were asked to rank the financial sources they use the most often in new technology development. They were asked to use the scale whereby the rank 6 meant the most preferable sources of financial capital, and 1 referred to sources that had been never used. The chi-square statistic, along with the associated probability of chance observation was computed for contingency tables. The analysis was conducted if the results were statistically significant at the "0,05 level". The results were also discussed to give an overview of the implementation of multidimensional scale analysis (MDS). MDS analysis investigated the chosen regions and the objects of cooperation with science and business angels funds' investments as well.

Analysis of research results – commercialization activities

In the analysis of research results, the financing of research and development activities of high-tech organizations was related to business-science cooperation. This supposition was based on a fact, that many authors stress the dominant role that financing of business-science cooperation plays in the process of the transfer of technology and research results, as well as in the technology development, particularly in emerging economies[19]. The financial mechanism of technology development and of research results commercialization, should be supporting cooperation of R&D institutions and the industry. Its function of stimulating development of regions and organizations is crucial for mining technological innovations, their adaptation and commercialization. Besides, fast pace of generating inventions and innovations does not always mean that they will be actually transferred to the economy. At the same time the diffusion of innovation can be taking place at a higher speed on the underdeveloped markets rather than on advanced ones[20]. The transfer of science and technology rests on cooperation, at least in the reference to the concept of purchasing of research results, licenses and patents.

In the surveyed population, almost two out of three respondents declared that they commercialize a technology or results of a research (in that pool, each tenth respondent always commercialized successfully). Nine out of ten respondents were introducing innovation in the organization such as: new processes, methods, products, technologies

18 An interesting study looking at the geographical distribution of business angels is describe by C. Mason, Venture capital: A geographical perspective, [in:] *Handbook of Research on Venture Capital,* ed. H. Landström, Edward Elgar, Cheltenham 2007, pp. 86–112.

19 *Transfer technologii z uczelni do biznesu. Tworzenie mechanizmów transferu technologii,* ed. K. Santarek, J. Bagiński, A. Buczacki, D. Sobczak, A. Szerenos, Polska Agencja Rozwoju Przedsiębiorczości, Warszawa 2008, p. 101–108; P. Sikka, Technology support and financing system for development and commercialization in India Perspectives, „Technovation" 1997, Vol 17, p. 707–714.

20 T. Markowski, op. cit., ss. 97- 104.

and improvements. Significantly larger group of the respondents was bringing research results to the market, rather than selling patents or licensing out. Three out of four respondents were commercializing research results, while every other organization was selling patents or licensing out.

Based on the results of the survey which depict a given case, and which can be treated only as exemplary, first and foremost it was established which financing sources were almost always used in the process of commercialization or in the surveyed institution. National grants are the prevailing source of external financing. The extent of utilizing other sources of financing for the development of technology, product, or organization was dependent on commercialization activity and successes in implementation. Apart from using venture capital, similar tendencies can be noticed in financing of technologies, innovation and organizations. Out of the institutions which always commercialized successfully, larger percentage of respondents was utilizing all sources of financing. Only in the case of using funds of their business partners, more respondents from the non-commercializing group or commercializing not always successfully, did indicate this source of financing in comparison to those commercializing always successfully.

Furthermore, those respondents whose organizations always succeeded in bringing results of research, patents or technologies to the market are the dominating group when it comes to the usage of venture capital funds. Almost every fourth organization almost always reaches for venture capital (fig. 1).

It can be noticed that the organizations which, according to the respondents, always succeed, use the financing from academic partners and business angels relatively more often. Higher percentage of declarations (which almost always used the funds of academic and not business partners) can confirm the fact, that commercialization of research results, technologies and patents in a substantial degree comes from the academic sector. Every fifth respondent came from business environment (micro, or small and medium companies) and from the academia, therefore the size of the section could not influence the resulting tendency.

Detailed analysis of the cross table revealing the relation between the singled out features and containing the answers of the two commercializing market segments (always positively commercializing implementations and not always successfully) confirms the idea that cooperation witch science – with the academia, can bring successes in commercialization activities more often.

Every sixth respondent declares his or hers organization as always successfully commercializing research results and never reaching for financing from academic partners. At the same time, in the segment of those trying to commercialize not always successfully, already one in three respondents came from an institution which never uses financing from academic partners. In case of accounts showing that the funds from academic partners were used in the process of commercialization of a given unit, almost twice as many respondents, who according to their statement always succeeded, stated that they almost always use partner financing for financing of science. (fig. 2) [21].

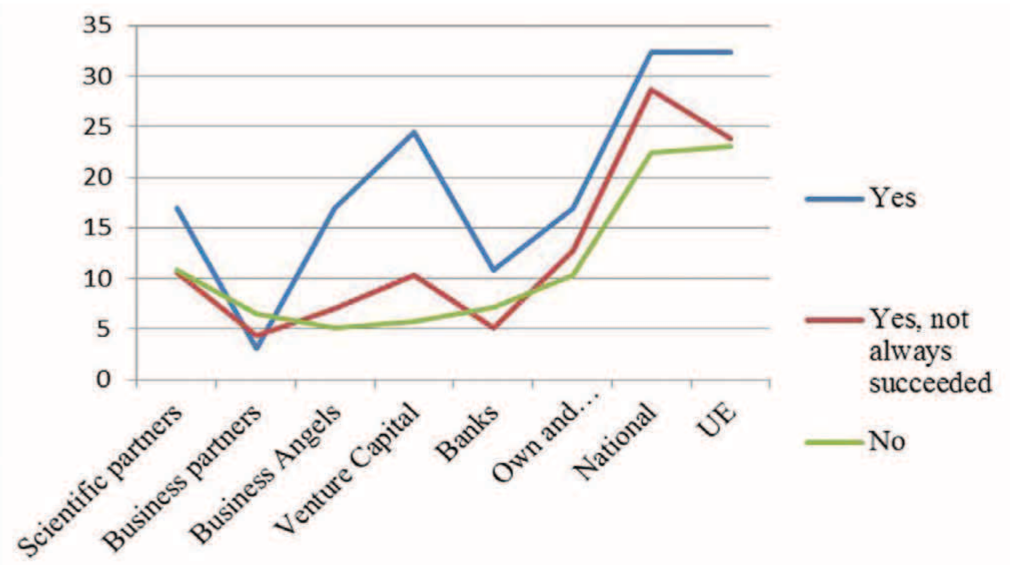

Fig. 1: Usage of sources of financing by the surveyed entities.
Source: Own elaboration based on the survey.

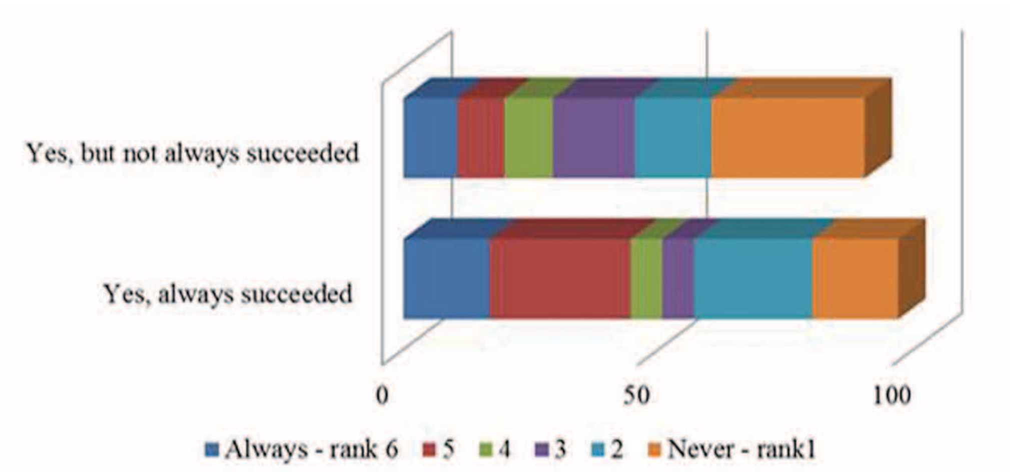

Fig. 2: Distribution of answers of the entities commercializing research results and technologies, and using funds from academic partners.
Source: Own elaboration based on the survey.

21 Two highest answers were analyzed (6 and 5) on the scale from 6 to 1, where 6 meant that we always use the funds, and 1 meant that we never use the funds.

Entities and funds of business angels also caught the interest of analyses that were being conducted. Kelly's[22] research of American market reveal that the typical business angel is a middle age investor, with experience in creating start-ups, relaying on a small group of advisors gathered in business angels associations, often financing ventures based on knowledge, and related to the field of their expertise. Spin-offs and spin-outs founded on the basis of research results, licensing agreements with scientific or R&D institutions, or contributed patents, are often counted into entities based on their owners knowledge. They originate in academic centers, or business support institutions discussed in this paper. Similarly to what was already presented in this paper, in case of using funds of academic partners, relatively more respondents who declare to always being successful in commercializing, almost always depends on financing from business angels (fig.3). Relatively bigger group of entities in the surveyed population, that commercializes not always successfully, can be counted into the segment of those that never use help of business angel funds (BA).

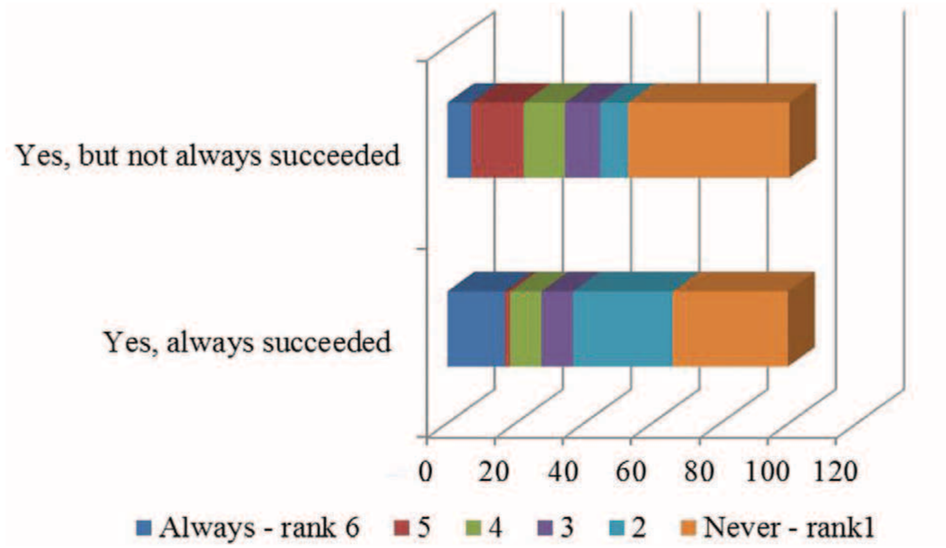

Fig. 3: Distribution of answers of the entities commercializing research results and technologies , and using funds from BA

Source: Own elaboration based on the survey.

Commercialization of science and technology is an area, where various elements of progressive processes can appear, and those processes include sales of technology, products, services, licenses and know-how. It also embraces new methods and techniques. What is more, commercialization success should be preceded by an introduction of changes

22 P. Kelly, Business angels research: The Road traveled and the journey ahead, [in:] *Handbook of Research on Venture Capital,* red. H. Landström, Edward Eldar publishing, 2007, p. 315- 331.

in the organization, in a form of e.g. new research, cooperation aimed at acquiring knowledge or supporting new ideas or projects with market potential. That is why the empirical study included not only the declarations whether the research results and technologies will be commercialized or not, but it also broadly interpreted development activities including: development of new technologies, processes, methods, products and services, organization, employees, know-how transfer, seeking new venture capital funds, purchase and sale of licenses. Innovation activities of the surveyed entities are primarily demonstrated in development of new products, services and methods. In the smallest degree by purchase and sale of licenses. Every fourth entity commercializing with problems, and every third always successfully commercializing, did buy licenses either in the last year, or during the research.

The process of looking for differences between the two surveyed segments, as a part of probing the market of those commercializing research results and technologies, can reveal who is dominating in different areas of innovation. Among the surveyed organizations which not always commercialize successfully, relatively more develops new processes, products, and is searching for new sources of financing when compared to the group of entities that always commercialize successfully. But bigger percentage of those respondents declared development of new methods, organizational innovations, progress of employees, and purchase and sale of licenses. With some degree of certainty it can be stated, that transfer of know-how requires capital funding, and often brand new one. That is why it is worth noticing, that the segment (which does not always commercialize successfully), which declared greater activity in know-how transfer, shows relatively bigger interest in acquiring new funding (fig. 4).

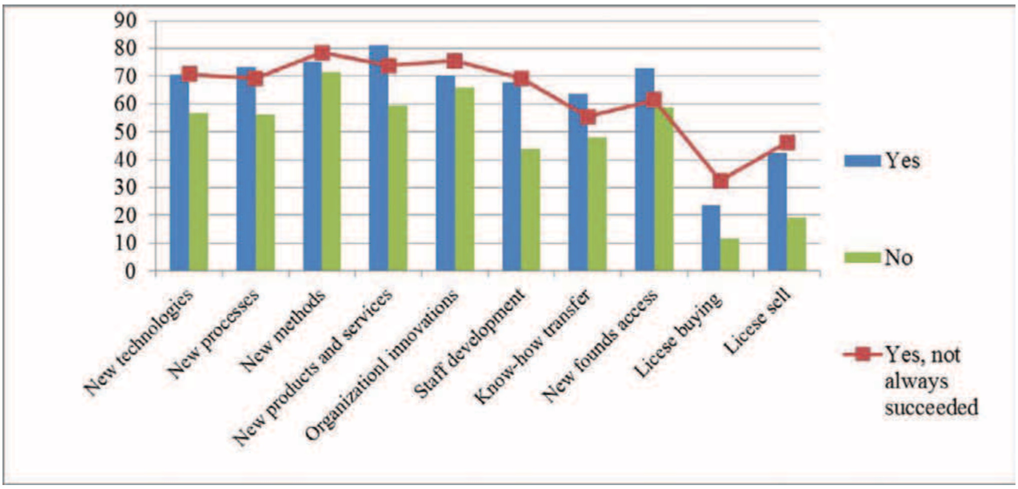

Fig. 4: Developmental activities of entities commercializing, and declaring lack of commercialization activities

Source: Own elaboration based on the survey.

Consumption Of Business Angels Found And Entrepreners Cooperation With Scientists

Further investigations, during the analysis of empirical material from market research, concentrated on consumption of funding from business angels, cooperation with scientific environment in seven selected regions, and in the segments declaring different innovative activities in the market or in the organization.

Multidimensional scaling was used to conduct the above analysis. First a map was created to position the surveyed regions: USA and Canada, Asia, South America, Australia and New Zealand, countries from so called "old" European Union, countries from so called "new" European Union (excluding Poland), Poland, other European countries and Israel, and remaining surveyed countries, according to the level of consumption of business angel funds and cooperation of business with academia.

Countries with relatively high level of business angel funding consumption and with high level of cooperation of business with academia are: United States, Canada, and surveyed countries from Asia, Australia and New Zealand. Relatively highest level of cooperation with academia and venture capital (business angels) was declared by survey participants from USA and Canada. Other European countries (such as Norway, Turkey, Island, Russia and Ukraine) showed high level of cooperation with academia, while at the same time showing relatively low level of venture capital funding consumption (business angel investments).

The UE 15 countries had a following market position: relatively high level of high-risk funds consumption (business angels), and low level of cooperation with academia. All the countries of the "new" European Union were positioned according to the multidimensional scaling analysis, in the area of low level of cooperation with academia and venture capital funds consumption. However, it should be noted that according to the survey Poland has a high level of cooperation with academia, comparable to the "old" EU countries. At the same time the level of business angel funding consumption in Poland was assessed as the lowest by the survey participants. Position of Poland in the profile of business angel funding consumption can be also perceived in the context of spendings on the entire R&D sphere. Among the twelve countries – the new members of European Union, Poland is ahead only of Cyprus and Bulgaria when it comes to spendings on R&D in relation to gross domestic product[23]. Lack of financing results in low level of inventions. This in turn, does not attract private funding, including business angels. Low level of

23 E. Gwarda-Gruszczyńska, D. Trzmielak, Innowacyjność i rola „Inicjatywy Technologicznej w rozwoju nowych technologii i podnoszeniu konkurencyjności przedsiębiorstw, [in:] Innowacyjność jako czynnik podnoszenia konkurencyjności przedsiębiorstw i regionów na jednolitym rynku europejskim, ed. J. Otto, R. Stanisławski, A. Maciaszyk, Politechnika Łódzka, Łódź 2007, p. 187–200.

business angel capital consumption can also indicate a low effectiveness of education. On the other hand, relatively higher level of cooperation with academia, then in other new UE countries can indicate progress and development of the business and science support institutions (which was the subject of the survey) (fig. 5).

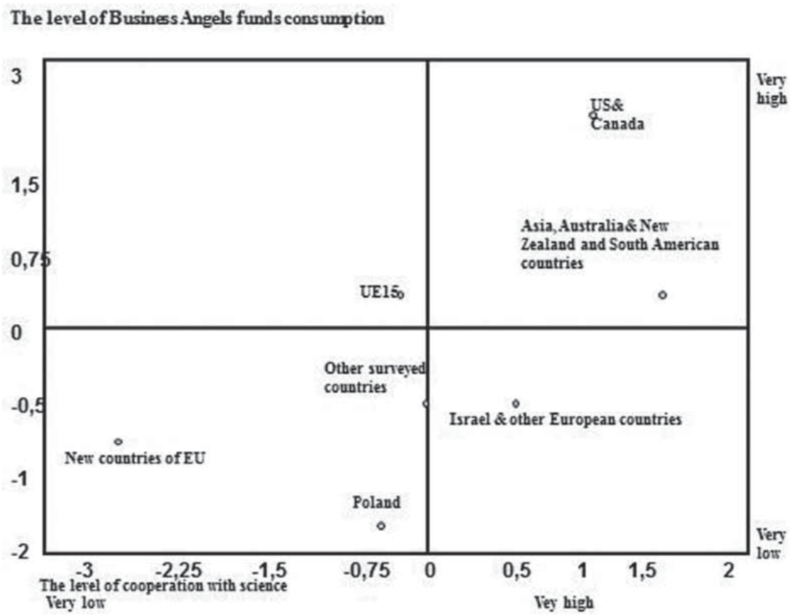

Fig. 5: The map of cooperation level with academia and business angels funds consumption in the surveyed regions, according to multidimensional scaling (measurement, squared Euclidean distance)

Source: Own elaboration based on the survey.

Another map of multidimensional scaling was developed for different areas of innovative activities. High level of cooperation with academia and business angels was revealed only for the activities related to the development of new technologies. Organizations, whose representatives declared to be active in the areas of technology transfer and in and out licensing, are perceived as institutions with high level of cooperation with academia and low level of business angel funding consumption. The most numerous group, similar in regard to the two features that were investigated is: development of new methods, processes, products and services and improvements in the organization. Entities declaring the above activities in the sample, can be – based on the collected empirical material – classified as relatively heavily using business angel funding, and weakly cooperating with academia. The last group of innovative activeness (seeking financing and improvement of personnel qualifications) in the survey sample, and according to MDS analysis, was positioned in accordance with low level of cooperation with academia, and low level of business angel funding consumption (fig. 6).

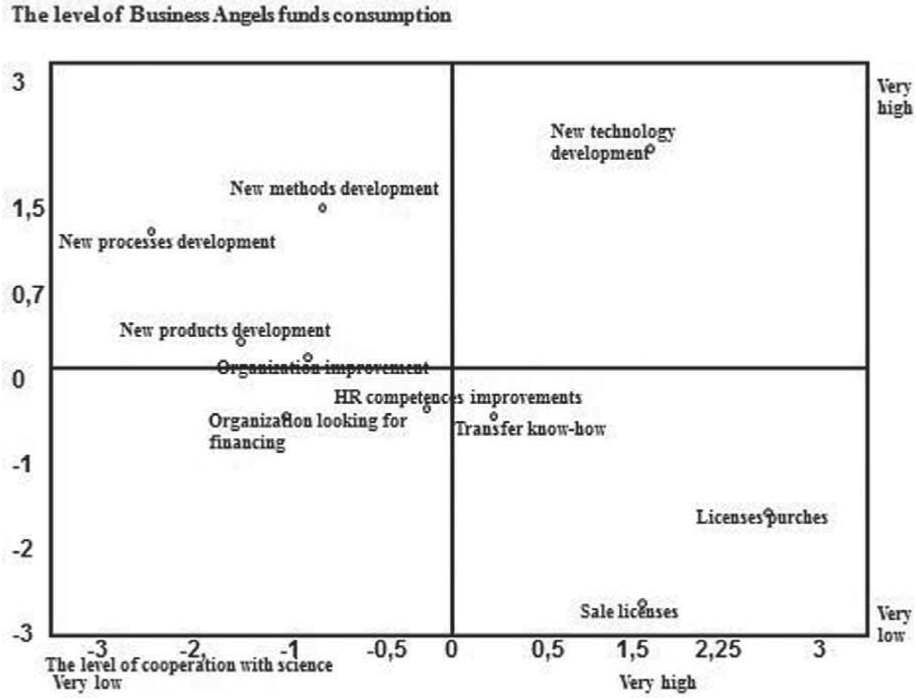

Fig. 6: The map of cooperation with academia and business angels funds consumption based on innovation activities in last year, according to multidimensional scaling (measurement, squared Euclidean distance)

Source: Own elaboration based on the survey.

Statistical analysis of contingency tables with innovative activity of the surveyed organizations and regions did not show, for the most part, characteristics of statistical dependence. The only statistical dependence occurs between know-how transfer, the eight types of surveyed organizations and seven regions of the world. According to the results of the survey, the highest percentage of organizations in the surveyed population, which declared know-how transfer are incubators and innovation centers. Around two thirds of those entities indicated activity in the know-how transfer. Further down the list are parks (research, and science and technology parks), institutes, and small and medium firms.

In case of regions of the world, over two thirds of respondents from Asia, South America, Australia and New Zealand are engaged in know-how transfer. In comparison, Poland as a know-how transfer environment is not rated highly. Only one in three representatives of surveyed groups stated that he is involved in the transfer of knowledge, including practical market or industry applications. (fig. 7).

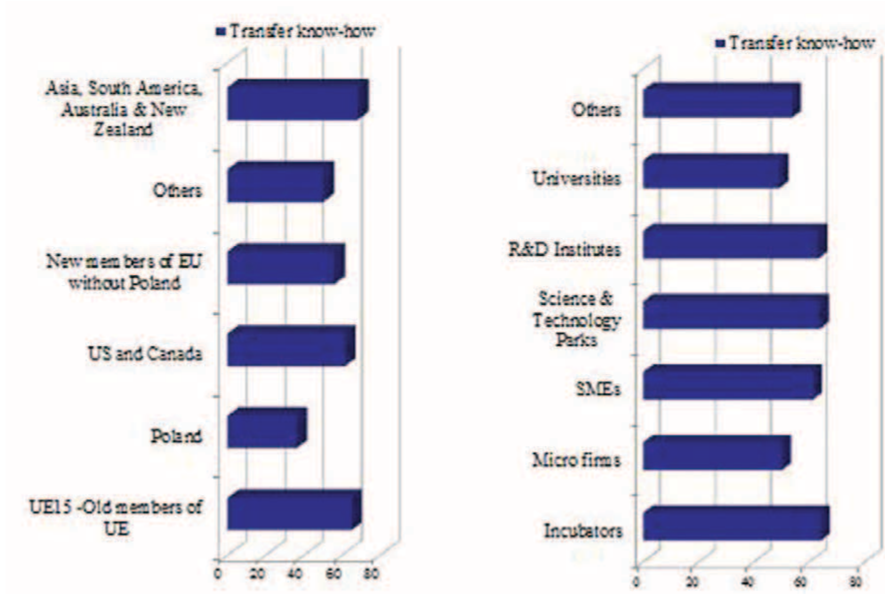

Fig. 7: Know-how transfer currently and in the previous year, according to the surveyed organizations and regions.

Source: Own elaboration based on the survey.

The last issue in the group of problems related to the cooperation between the academia and the industry, and financing of the pro-development activities including commercialization, is the relation between experience in commercialization and sources of financing used for development and implementation activities. Experience in commercialization is understood as a number of commercialized results of research, sold patents and licenses. Statistical analysis showed relation only between: commercialization of research results and consumption of business angel, private, and mixed funds; out licensing and venture capital, UE, private and state funds, as well as sales of patens and industrial funds. Together with the increase in experience in the surveyed population there also grows percentage of people declaring that they are using different sources of financing. Every fourth responded, who has commercialized at least 1 to 5 research results, and every third that has experience of having implemented more than 5 research projects, uses business angel financing. Every other person with experience in the sales of more than 5 licenses, was declaring to be building commercialization model based on venture capital funding. The only deviation from the prevailing trend is the relatively higher percentage of innovators selling licenses with modest experience (1 or 2 licenses sold), then with medium experience (3 or 5 licenses sold), and those with considerable experience using the state funds. (fig. 8).

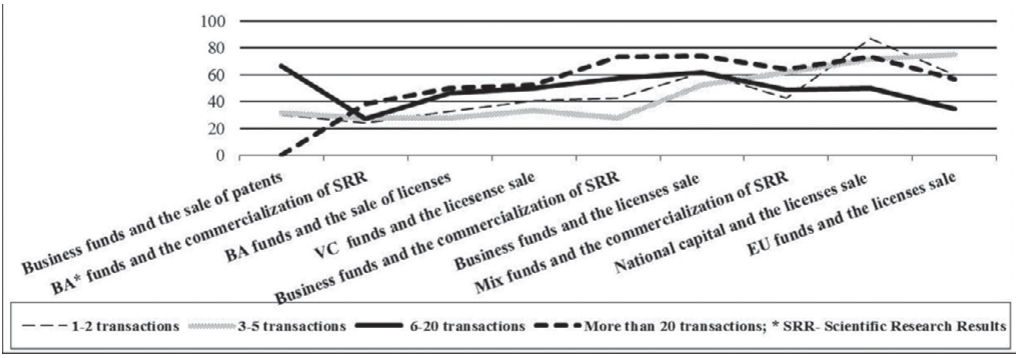

Fig. 8: Experience in commercialization and used sources of financing (answers 6,5,4, where 6 stands for almost always uses, and 1 stands for never)

Source: Own elaboration based on the survey.

Summary

The role of the commercialization is crucial, yet much public and private money goes to new scientific teams which never launch products on the market. It is frequently difficult to distinguish the idea from the expression, since the decision is inevitably ad hoc. Because the line between idea and expression is elusive, financing must pay particular attention to the pragmatic considerations that underline new technology development policies. Furthermore, the innovation is often based on cooperation between the research sphere and industry. The transfer of licenses which are based on the results of scientific research involves not only the transfer of a patent, but of its accompanying know-how. In this context closer cooperation between academia and business becomes a natural part of the ongoing process.

The analysis has been conducted to indicate the insights and factors influencing the relationships between science and business in scope of commercialization financing. In this study particularly we focus on Business Angels funds. It can be assume that the investments from Business Angels prompt commercialization process and stimulate success in commercialization. The highest level of sciences and business cooperation and Business Angels funds consumption has been found in United State and Canada. Business Angels funds and science and business cooperation engagement in cooperation inspire the new technology development.

The presented study combined the high-tech market players and countries to emphasize the significant importance of partnership in commercialization process and an appropriate financing and funds rising for research and developments. Although the importance of measured chosen elements for new technology commercialization was confirmed in studies, the possible influence of additional factors can be taken into consideration. Also we can see the weaknesses points of the survey. One of the geographical area did not analyse deeply is Asian high-tech market. The language barriers made difficulty to reach many organization in this region. Unfortunately the domination of European countries has influenced the results.

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StemDev Medellín and an Instrument Proposal to Assess Regional STEM-Economic Development Alignment

Cliff Zintgraff

IC[2] Institute, The University of Texas at Austin

Carol Fletcher

Center for STEM Education, College of Education,
The University of Texas at Austin

Jennifer Jordan-Kaszuba

Center for STEM Education, College of Education,
The University of Texas at Austin

Joules Webb

Prefreshman Engineering Program,
The University of Texas at San Antonio

Abstract

This paper proposes development of an instrument to help regions measure the integration of their STEM (science, technology, engineering, mathematics) education efforts with their regional economic development goals. The StemDev Actor Perceptions Instrument will measure the degree to which regions are organizing across the secondary education, higher education, government, industry and community sectors, from the perspective of actors in the system. This paper is primarily concerned with the mutual perceptions

of secondary education vs. the other named sectors. In the instrument's first version, multiple provisional constructs will be measured, with constructs derived from a literature review and from the experience of the authors running integrated STEM and economic development programs. Providing a specific case and context is the StemDev Medellín (Colombia) program. Early findings from StemDev Medellín are shared, and they inform and add context to the instrument proposal. A tool like the one described can be used to establish baselines and measure programs that seek to align STEM and economic development programs in a region. When fully developed, the tool can contribute to quality of life for citizens in regions with knowledge-driven economies.

StemDev Medellín and an Instrument Proposal to Assess Regional STEM-Economic Development Alignment

The current paper proposes development of an instrument to help regions measure the integration of their STEM education efforts with their regional economic development goals. This paper uses the term *StemDev* to describe such efforts and systems. The *StemDev Actor Perceptions Instrument* will measure the degree to which regions are organizing between the secondary education sector and higher education, government, industry and community (HGIC) sectors, from the perspective of actors within the system. In its first version, multiple provisional constructs will be measured, with constructs derived from a literature review and from the experience of the authors running StemDev-type programs; also in the first version, emphasis will be placed on the relationship between secondary education and employers. Formal quantitative methods will be applied over time to derive insights and improve the construction of the instrument.

This first proposal is informed by the ongoing *StemDev Medellín* project. The project is a partnership between institutions in Medellín, Colombia and Texas, USA. In Medellín, the project managing partners are the City of Medellín Office of the Secretary of Education; Parque Explora, the city's science and technology museum; and Sapiencia, the city's coordinating agency for higher education. In Texas, the program is led by the IC^2 Institute at The University of Texas at Austin (UT Austin); co-led by *Texas Regional Collaboratives,* a teacher in-service training program in the Center for STEM Education, College of Education, UT Austin; and supported by the Prefreshman Engineering Program (PREP) at The University of Texas at San Antonio (UTSA).

The StemDev Medellín project has two major components. First, higher education institutions are receiving project-based training on moving research-driven technology innovations to market, and they are receiving technical assistance building innovation/entrepreneurship education programs for university students. In the second major program component, secondary schools are receiving training on project-based learning (PBL) in the context of the city's science and technology plan and priority industry clusters. Across all components are strong efforts to connect secondary schools with HGIC partners, and to build bridges across sectors. For example, university faculty are assisting with the development of PBL curriculum for secondary schools, and university entrepreneurship courses may eventually be adapted for older secondary school students. The StemDev Medellín program is grounded in both local economic development and global citizenship, and has fundamentally incorporated arts, most notably in the context of creativity, design, and innovation, and in a manner consistent with the long-term history and culture of the region. *STEAM-LABS* was adopted as the name of the program for secondary schools, teachers and students, with the A explicitly representing the arts component.

The STEAM-LABS project provides an example of why it is important to understand the nature of the relationship between secondary educators and the HGIC sectors. STEAM-LABS training is based on PBL training materials from the Buck Institute for Education (Markham, Larmer, & Ravitz, 2003). These materials emphasize authenticity, adult connections, and active exploration, among other criteria, as part of the rubric for evaluating PBL projects. These criteria drive demand for interaction with employers, and in many cases, with private industry. For example, teachers might need to know how electricity is provided to a village to create an authentic project about rural energy access. Teachers might need to interact with web design firms to understand the best practices for making a web page for an advocacy group. These teachers' students may need to hear directly from professionals to reach full appreciation of the field, what is involved in the field, and the difference it makes (Kamoun & Salim, 2007; Gorgone, Davis, Valacich, Topi, Feinstein, & Longenecker, 2002). However, based on the STEAM-LABS experience, not every outbound request from secondary schools for partnership is filled. How do secondary educators, on the one hand, and HGIC actors, on the other hand, view one another, within the context of these STEM-driven relationships?

This paper advocates for the position that while regional economic development and STEM education are important independently, they are strongest and mutually reinforcing when approached together. A review of the literature supports this viewpoint. This paper will explore the important role of regions in economic development, the positive dynamics that develop in regions around industry clusters, and the importance of relationships between secondary education and the HGIC sectors (Mills, Reynolds, & Reamer, 2008; Kitson, Martin, & Tyler, 2004; Porter, 1998; Gibson, Kozmetsky, & Smilor, 1992). In particular, the *technopolis model* (Gibson et al., 1992) highlights the need to work together across sectors, and recent technopolis research (Gibson & Butler, 2013) makes clear how regional leaders who work across sectors build fundamental competitive advantage for a community. The U.S. National Academy of Sciences (2007) highlighted the importance of building STEM foundations in early secondary and even primary-aged students. For these students, when educators deliver instruction in real-world context, benefits can be seen in student motivation and academic outcomes (Daggett, 2010, 2007; Stone, Alfeld, & Pearson, 2008; U.S. National Academy of Sciences, 2007; Mergendoller, Maxwell, & Bellisimo, 2006; Markham et al., 2003). The underlying traditions of contextual and social learning were defined by the seminal work of Piaget (1954) (constructivist foundations), Vygotsky (1978) (social constructivism) and Dewey (1997, 1900) (interaction of thought and practice).

The proposed instrument will first be developed with multiple provisional constructs. These constructs will be derived from a literature review, and from the experience of the authors running integrated STEM and economic development programs, including StemDev Medellín. Development of questions will begin with identification in this paper of *conceptual areas* from which questions can be derived. Once developed, the provisional instrument will be deployed with educators, government and other policymakers, community organizers, and employers, including private industry. It is planned that early use will place some degree of emphasis on employers, consistent with the goals of the programs for which initial use is planned. Formal quantitative methods, including factor analysis and instrument reliability measures, will be applied to develop the instrument over time and establish a history of reliability and validity across diverse populations.

Definitions

Several concepts are referred to frequently in this paper. Therefore, definitions are offered to enhance clarity, for the terms *STEM, STEAM, HGIC, secondary education, higher education, government, industry, community, employer* and *region*.

STEM is an acronym for science, technology, engineering and mathematics. The acronym was first used by Ramaley in 2001 (Christenson, 2011), but used previously in alternative forms (Christenson, 2011; Sanders, 2009). *STEAM* is an acronym for STEM-plus-arts, and recognizes the role of arts and humanities in STEM learning and technology innovation (Christenson, 2011; Eger, 2010). A central idea of STEM/STEAM education is that topics in these fields are best taught in an interdisciplinary fashion (Christenson, 2011, quoting Ramaley). When used in this paper, STEM/STEAM expressly refers to the topics taught within at least a broad plan of interdisciplinary teaching and learning. It does not refer to the individual subjects of science, technology, engineering, arts and mathematics when intentionally taught in isolation. Because writing STEM/STEAM is inelegant, and because STEM is more widely in use, this paper will simply use the STEM convention except where greater clarity is required, without the intention of excluding arts, but acknowledging the currently more settled roles of science, technology, engineering and mathematics in most STEM environments.

As defined earlier in this paper, *HGIC* is an acronym for *higher education, government, industry* and *community.* Taken together with secondary education, these are the five sectors for which this paper advocates strong cooperation to advance economic development. Because this paper centers on secondary education, HGIC is defined as a shorthand method to succinctly refer to the other four sectors. *Secondary education* refers to later pre-college education; in the U.S., this is usually grades 6–12, and in the authors' experience in Medellín, grades 6–11. *Higher education* refers to any college, university or other post-secondary education offered by an accredited institution. *Government* can refer to all local, regional and national government institutions, but refers to local or regional governments in this paper unless otherwise noted. *Industry* refers to private, for-profit companies. *Community* refers to non-profit institutions, NGOs, and other institutions formally constituted but lacking the goal of building wealth for individual owners.

At times, the term *employer* will be used to describe those who hire STEM and other workers. It is not only industry that hires STEM workers (Neal, 2014). For example, Morrow and Smith-Heimbrock (2014) wrote about the important role of the U.S. federal STEM workforce. A reference by this paper to *employers* refers to all who hire and pay salaries, not just industry.

A *region* is a physical location defined by geography, political boundaries, and/or cohesion around particular criteria or purpose (Mills et al., 2008; Cooke, 2003). Regions help define industry clusters, which are "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 1998, p. 199). While one might emphasize geographies, or perhaps political boundaries, Cooke & Memedovic (2003) argued that regions, while usually geographic in nature, are better defined by their homogeneity around a set of criteria, and/or by an element of cohesiveness. Nevertheless, this paper will note that its example region, Medellín, Colombia, is defined by all of these things: geography (the Medellín Valley), political boundaries (the city government), and by cohesion around purpose ("Medellín, todos por la vida" (all for life)) (Alcaldía de Medellín, 2014).

Literature Review

This paper's literature review is organized around five topics. First, regions are advanced as having a central role in economic development. Second, STEM is presented as a movement, and as motivational and supportive of regional cooperation. Third, STEM's theoretical foundations of constructivism and inquiry are established. Fourth, it is shown from the literature how constructivism and inquiry support interactions between sectors and the building of STEM foundations in young students. Fifth, a summary is provided from the literature review that highlights promising conceptual areas for instrument development.

The Central Role of Regions in Economic Development

Zintgraff, Green and Carbone (2014) wrote about the central role of regions in economic development. They noted how authors like Mills et al. (2008), Cooke and Memedovic (2003) and Porter (1998) all contributed to specifying a region as defined by geography, political boundaries, and cohesion around purpose, with the priority of those criteria varying somewhat among those authors, and applied in ways sensitive to a specific region's circumstances. A common theme in their writing was the relative importance of regions vs. larger entities; contrasts were specifically made with U.S. states and national/federal governments. Cooke (2001) called regions the "more natural economic zone" (p. 4), with regions becoming more capable of acting on their own to build domestic and international partnerships and to recruit investment from all over the world. He referred to the "to and fro of adjustment between companies, markets, public authorities, research institutes, training institutions and social partners" as a self-reinforcing system that works to a region's advantage. According to Kitson et al. (2004), "there is now widespread agreement that we are witnessing the 'resurgence' of regions as key loci in the organization and governance of economic growth and wealth creation" (p. 991). Sanz-Menéndez & Cruz-Castro (2005) noted the convergence of regional policy and technology policy concerns, and the associated challenges in integrating those policies.

Reinforcing the regional focus argument is the technopolis model (Gibson et al., 1992; Smilor, Gibson, & Kozmetsky, 1989). These authors proposed a *technopolis wheel* that evoked the idea of a holistic regional economic development system. The metaphor offered is a wheel on which technology-driven economic development advances. The major spokes in the wheel are universities, large corporations, emerging companies, federal government, state government, local government, and support groups. Within the state government spoke, one of the two mini-spokes is *educational support,* evoking public secondary schools. Smilor et al. are clear that there is interplay among the sectors, a "balance between the public and private sectors" (p. 50). For example, an important factor in economic development is "attraction of major technology companies" (p. 50), and companies care about "related research, education, and training institutions such as universities, community colleges, and workforce training programs" (Mills et al., 2008, p. 9). This further confirms the importance of regional strategies. "Ultimately competitive regions and cities are places where both companies and people want to locate and invest" (Kitson et al., 2004, p. 997).

It must be noted, however, that secondary education seems to play a reduced role. The technopolis wheel relegates secondary education to a sub-spoke within local government. Mills et al. (2008) talked about post-secondary education, but they do not mention secondary education as a focus of major technology companies. However, this paper will demonstrate through other literature a trend toward HGIC engagement with secondary education, and this literature will suggest significant growth in the relationship between secondary schools and industry.

Champions and influencers in regions

Writing about building effective connections across sectors of all types, Gibson and Butler (2013) highlighted the need for people who work proactively across traditional boundaries, if cross-sector efforts are to be effective. They used the term *influencers,* and they highlighted two kinds of influencers. Second-level influencers do the groundwork of making those connections happen. First-level influencers provide executive support, making resources available, and providing political cover, through their extensive cross-sector network. Cooke's (2001) description of a technopolis is consistent with these ideas. Cooke noted that technopoles will survive "only if they absorb the lessons of interactive innovation systems, by enhancing social capital, networking and intermediary activity" (p. 38).

The STEM Movement: Regional Cooperation, Because Everyone Owns STEM

Many people think of STEM education as a program, and often, their idea of STEM is in terms related to their own work and viewpoint (Breiner, Harkness, Johnson, & Koehler, 2012; Angier, 2010). However, Breiner et al. referred to STEM as a "movement" (p. 3). The idea of STEM as a movement allows for a broader definition, and one where individual viewpoints are not conflicting, but individually valid, and give parties shared ownership in the locally-instantiated STEM programs they create. Such individual, complementary viewpoints support cooperation across sectors.

For example, in Breiner et al.'s (2012) literature review, they discussed how educators, society, politicians, and individuals view STEM. In each case, acknowledgement of STEM as an integrated approach was at best secondary, with primary views focused on individual work or life perspectives. Educators viewed STEM through their disciplines, and unlike the way the disciplines naturally integrate outside the school room, they were not taught this way in the classroom. From the perspective of politics and society, most programs were reported to exist in silos. Just like science is often reported to be *taught* "not the way science is *done*" (p. 5, citing Schwartz & Lederman, 2002), STEM is "taught…much different than the way STEM is done" (Breiner et al., p. 5). From an individual perspective, "people do not have an interdisciplinary understanding of STEM" (p. 6). Overall, there "exists a knowledge and communication gap between policy makers, universities, K-12 school districts, and the general public, e.g., parents" (p. 6).

Yet in the "real world" (Breiner et al., 2010, p. 5), STEM professionals naturally integrate the components of STEM. Engineers must understand math, science and technology; chemists require in-depth understanding of math, science and technology; STEM in the real world embodies the "purposeful integration of the various disciplines as used in solving real-world problems" (Breiner et al., 2010, p. 5, citing Labov, Reid, & Yamamoto, 2010; Sanders, 2009). One can see this cooperation embedded in the Buck

Institute for Education PBL training materials (Markham et al., 2003), in their ideas of *driving questions,* real-world relevance, and authentic adult connections. Numerous education researchers and studies have advocated for the importance of this integration (Sanders, 2009; U.S. National Academy of Sciences, 2007; Hmelo-Silver, Duncan, & Chinn, 2007; Edelson, Gordin, & Pea, 1999; U.S. National Research Council, 1996). With technopolis-like cooperation across sectors, the HGIC sectors, and industry in particular, can add value to the core teaching practices of secondary educators.

STEM Theoretical Foundations: Constructivism and Inquiry

The three schools of thought about how people learn are behaviorism, cognitivism and constructivism (Ertmer and Newby, 1993). Behaviorism views learning as responding to stimuli, with no concern for cognition. Cognitivism views learning as happening inside the mind. It is concerned with mental structures and views the learner as actively part of the learning process. Constructivism similarly concerns itself with how the mind learns, but goes a step farther and sees the mind as creating its own reality. Or per Ertmer and Newby (1993, p. 62):

> Constructivists do not share with cognitivists and behaviorists the belief that knowledge is mind-independent and can be 'mapped' onto a learner. Constructivists do not deny the existence of the real world but contend that what we know of the world stems from our own interpretations of our experiences. Humans create meaning as opposed to acquiring it.

Many STEM programs build on constructivist learning theory and techniques of inquiry-, problem- and project-based learning (Abdulwahed, Jaworski, & Crawford, 2012; Bybee, 2010; Sanders, 2009). This theoretical approach strongly supports inquiry-based approaches to education, with that inquiry involving partners from outside the school system-proper. The informal sample encountered in this literature review showed constructivism as the primary theoretical foundation for inquiry learning (Hmelo-Silver et al., 2007; Prince & Felder, 2006; Colburn, 2000; Edelson, Gordin, & Pea, 1999). The literature also strongly suggests that strong guidance during inquiry learning is essential to achieve learning outcomes (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Hmelo-Silver et al., 2007, responding to the inquiry guidance critique of Kirschner, Sweller, & Clark, 2006). Inquiry learning is described as: (1) open-ended, hands-on, student-centered (Colburn, 2000); (2) including strong guidance (Hmelo-Silver et al., 2007); and (3) "authentic to science practice…with questions generated by learners" (Edelson et al., 1999, p. 393). Constructivism rests on, among others, the work of Dewey (1997, 1900), who advocated inquiry as learning-in-context that helps learners connect new knowledge to existing knowledge, and also to the work of Vygotsky (1978), whose Zone of Proximal Development highlighted the role of an expert helping a learner. Vygotsky's ideas underpin social constructivism, the idea that learning happens in groups, and that we learn from one another.

The ideas put forth by constructivism—respecting empirical data, creating one's own meaning, learning with the help of experts, learning in groups, and leading one's own learning—are a solid foundation for the involvement of HGIC sectors in education. Partners from HGIC sectors are working on real problems. They integrate information across disciplines to solve these problems. They are experts who, in partnership with education professionals, can help students see and appreciate context, appreciate careers, and learn academic content in context (Breiner et al., 2010; Labov et al., 2010; Sanders, 2009).

Inquiry Learning and Constructivism: A Foundation for Learning with HGIC Sectors

Inquiry learning and constructivism are compatible with interaction with the HGIC sectors; more specifically, STEM-based contextualized approaches to teaching and learning form a foundation for interaction with HGIC sectors. Stone et al. (2008) addressed the impact of learning mathematics content within the explicit context of real world problems. Their research indicated that students who were taught mathematics in the context of various applied Career and Technology courses in high school significantly outperformed peers in traditional mathematics classes on two measures of standardized math achievement, after one school year of instruction.

There is also a growing research base supporting project-based learning (PBL) as a specific model for connecting core content knowledge to real world problems. Studies have reported increased student achievement related to core academic knowledge, and increased student motivation (Mergendoller et al., 2006; Thomas, 2000; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). In a six-year study of the impact of Project Lead the Way (PLTW), a pre-engineering project-based course, Van Overschelde (2013) found that PLTW students outperformed matched, non-PLTW students in mathematics, with a higher percentage of PLTW students scoring at or above the college-ready criterion on a state standardized mathematics test, and with a higher percentage enrolling in Texas higher education institutions.

Three areas in the literature provide a further opportunity to examine the assertion of constructivism, inquiry learning and STEM-based instruction as a foundation for interaction with HGIC sectors. The assertion can be examined through the literature of global citizenship, career pathways/programs of study, and establishing early foundations for young STEM students. These concerns are compatible with HGIC interactions, and are drivers toward such interactions.

The foundation of global citizenship

If embedding real-world problems in instruction is an enduring attribute of STEM, then one should consider how to maximize the meaning those problems will carry with students. In the UNESCO (2014) paper *Global Citizenship Education: An Emerging Perspective,* it is argued that globalization increases "the importance of values, attitudes and communication skills as a critical complement to cognitive knowledge and skills" (p. 1). Viewed in this manner, concerns of global citizenship serve the role of maximizing for learners the meaning associated with problems, expanding beyond the technical aspects of that meaning, and into values, attitudes, communication skills, and other 21st century learning objectives.

Such learning for students can be the basis for creating future economic value. This paper's introduction used the examples of rural energy delivery and web-driven social advocacy as problems for which one might interact with HGIC partners. Such problems are two of many common problems seen around the globe. The Medellín science and technology plan (Echeverri, 2014) highlights how solving global problems has the side effect of building local knowledge, skills and assets. The knowledge, skills and assets retained locally become raw materials for regional economic development as they are used to address global problems.

Programs of Study

Above, it was noted how the technopolis model assigns only a subordinate role to secondary education (Gibson et al., 1992), and how major technology companies have not focused on secondary education connections (Mills, Reynolds, & Reamer, 2008). However, there are current and emerging activities that suggest this engagement is increasing significantly. One such activity is the development of *Programs of Study.* There has been recognition among U.S. colleges and universities that it is not sufficient to make available course sequences, options for graduation plans, and articulations with other higher and secondary institutions. There is a further, important need to provide to students and parents the guidance and support services that will help them navigate the complex options available—to navigate both the written and the unwritten rules (Zeidenberg, Cho, & Jenkins, 2010; Fike & Fike, 2008; Conley, 2007; Habley & McClanahan, 2004). Students require "college knowledge" (Conley, 2007, p. 17) to successfully navigate higher education.

To provide a tool for such efforts, the U.S. Department of Education Office of Vocational and Adult Education (OVAE) (2010) defined the *Programs of Study* framework. This framework drives institutions to not only specify their internal course sequences and options, and their scholarship resources, but also extracurricular activities, internships, mentorships, housing options, childcare options, and connections from secondary schools. The Program of Study is not constrained by the boundaries of the higher education institution, but connects backwards to secondary schools, sideways to support programs and professional opportunities outside the school, and forwards to employment and graduate programs. Programs of Study help define the actors who should be engaged in community strategy for alignment. They specifically integrate academics with industry-driven content and technical education, an idea also advocated by Hoachlander and Yanofsky (2011), Daggett (2010, 2007), and Sanders (2009).

Early foundations for young STEM students

Independent of regional economic development drivers, numerous studies have highlighted the importance of establishing early STEM foundations in students. The U.S. National Research Council (1996) advocated increased science inquiry activities for all students. Rogers and Portsmore (2004) advocated for elementary engineering education, and Watters and Ginns (2000) for elementary science learning and relevant teacher pre-service education. Early engagement is advocated for the academic preparation and social acclimation of tween (pre and early teen) students in STEM education (Games for Learning Institute, 2014; U.S. National Academy of Sciences, 2007). Daggett (2010, 2007) advocated for increased Career and Technical Education (CTE) done in a way that integrates strong academics, evoking the interdisciplinary nature of STEM education (Breiner et al., 2012).

Early STEM foundations are important because STEM education is particularly hierarchical. In *Rising Above the Gathering Storm* (U.S. National Academy of Sciences, 2007), science and engineering education is called an endeavor that must begin in middle school[1]. The Games for Learning Institute (2014), at the NYU Steinhardt School of Culture, Education and Human Development, said that STEM education must start in middle school. Rogers and Portsmore (2004) and Watters and Ginns (2000) highlighted lessons appropriate for elementary school, and gave examples of interactions with the HGIC sectors. Rogers and Portsmore noted engagement with external partners around (1) early coding lessons; (2) building of simple robots; (3) use of communication platforms that enable cross-sector interaction; and (4) longer term adaptation of technology by external partners to meet classroom needs. These programs find age-appropriate ways to communicate mathematics, science and engineering concepts to young students, using technology that is within their reach, with strong scaffolding (educational support) provided by an engaged teacher.

1 In the U.S., middle school is usually grades 6 through 8.

Indicators of increasing engagement

The authors were not able to locate rigorous studies focused on the idea that industry/employers and secondary education have an increasing number of contacts. However, anecdotal data and proxies can be provided that suggest increasing engagement. At the U.S. federal level, Scott (2012), citing the U.S. President's Council of Economic Advisors (PCAST) report on information technology R&D (2010), noted the PCAST goal of "at least 200 new highly-STEM-focused high schools and 800 STEM-focused elementary and middle schools over the next decade" (p. x). In turn, one might deduce that the 91 T-STEM (Texas STEM) academies designated by the Texas Education Agency (2014) for the 2014–2015 school year are inspired, or at least indirectly related, to this federal initiative. The T-STEM academies are specifically designed for sixth through twelfth graders, with an instructional focus on STEM, and with the goal of increasing the number of students who study and enter STEM careers. As Scott (2012) noted by example, STEM schools provide their teachers resources for project-based learning (PBL). The expansion of PBL is itself a possible proxy for the expansion of HGIC contacts, since it is argued that PBL requires greater involvement of industry and employers (Markham et al., 2003).

One can also consider the multiple types of professional tools that are being placed in classrooms, tools for which it is natural to expect the involvement of industry and employers for advice, classroom speaking, mentorship and internships. The tools seen are from computer science/computational thinking (Barr & Stephenson, 2011; Brophy, Klein, Portsmore, & Rogers, 2008; Rogers & Portsmore, 2004), geographical information systems (Broda & Baxter, 2003; Edelson et al., 1999), engineering (Dearing & Daugherty, 2004), and media literacy (Christ & Potter, 1998). Some of these efforts are happening at both secondary and higher education levels. Professional connections are also found in special programs and competitions. For example, in the PREP program at The University of Texas at San Antonio (UTSA), Toyota Motor Manufacturing of Texas funds a field trip to their manufacturing plant, which includes a question-and-answer session between students and on-site engineers (San Antonio Prefreshman Engineering Program, 2013). One FIRST Robotics web site lists nine corporate sponsors (FIRST: The Alamo Region, 2014).

Promising Areas for Psychometric Measures from the Literature

This review suggests a number of conceptual areas from which provisional questions might be drawn for the StemDev Actor Perceptions Instrument. This instrument can be deployed in the different sectors (secondary education, and the HGIC sectors), and results compared between the sectors. Through factor analysis, constructs might be drawn from the conceptual areas. Table 1 lists promising conceptual areas. As the reader reviews the table, the reader is encouraged to consider what different perceptions might exist between actors in secondary education, higher education, government, industry, and community organizations.

Table 1: Promising Conceptual Areas for Constructs, based on Literature

Conceptual area	Derived from
Economic development	
Regional economic development	Mills et al. (2008), Kitson et al. (2004), Porter (1998), Gibson et al. (1992)
Technology-driven economies	Same as prior
Regional industry clusters	Porter (1998)
Regional technology-driven economic development plan	Cooke (2001), Sanz-Menéndez and Cruz-Castro (2005)
Higher education's role in economic development	Mills et al. (2008), Gibson et al. (1992)
Secondary education's role in economic development	U.S. National Academy of Sciences (2007), Gibson et al. (1992) (technopolis)
STEM education	
STEM education as a concept	Sanders (2009)
Public literacy in STEM education	Breiner et al. (2010)
STEM's presence in colleges and universities	Breiner et al. (2010), Sanders (2009)
STEM's presence in secondary schools	Rogers and Portsmore (2004), Watters and Ginns (2000)
Interdisciplinary application of STEM	Daggett (2010, 2007), Breiner et al (2010)
Rigorous academic content in STEM	Daggett (2010, 2007), Hoachlander and Yanofsky (2011), Sanders (2009)
Authentic content based on real-world concerns and/or global citizenship	UNESCO (2014), Markham et al. (2003), U.S. Department of Education Office of Vocational and Adult Education (2012)
21st century skills in STEM	U.S. National Academy of Sciences (2007)
Integration with arts and humanities disciplines	Christenson (2011), Eger (2010)
Focus on early STEM foundations in pre-teen students	Games for Learning Institute (2014), U.S. National Academy of Sciences (2007)
Teacher capacity to deliver using STEM-compatible pedagogy	Scott (2012), Alfieri et al. (2011), Mishra and Koehler (2008), Hmelo-Silver et al. (2007), Markham et al. (2003), Hall and Hord (1987)

STEM and regional economic development alignment	
STEM program alignment with regional technology-driven economic development plan, in higher education	U.S. National Academy of Sciences (2007), Mills et al. (2008)
STEM program alignment with regional technology-driven economic development plan, in secondary education	U.S. National Academy of Sciences (2007), Mills et al. (2008)
Role of higher education in secondary STEM education	U.S. Department of Education Office of Vocational and Adult Education (2013), Barr and Stephenson (2011), Christ and Potter (1998)
Role of community partners in secondary STEM education	Gibson and Butler (2013)
Industry engagement with higher education STEM programs	Mills et al., 2008
Industry engagement with secondary education STEM programs, for example, through speaker's bureau, curriculum advice, real-world content, intermittent funding, program volunteers, mentors, internships, scholarships, sustained funding	Markham et al. (2003), U.S. Department of Education Office of Vocational and Adult Education (2013), Barr and Stephenson (2011), Broda and Baxter (2003); Christ and Potter (1998)
Regional career promotion	U.S. Department of Education Office of Vocational and Adult Education (2013)
Regional pathways and programs of study	Zeidenberg et al. (2010), Fike and Fike (2008), Conley (2007), Habley and McClanahan (2004)
Regional champions who work across boundaries	Gibson and Butler (2013)
Regional executive champions who enable cross-sector activities	Gibson and Butler (2013)

About StemDev Medellín and the STEAM-LABS Program

A coordinated effort is underway to impact Medellín's secondary ("K-11") schools and the city's three technical universities. This effort is being led by Medellín's Secretary of Education and local institutions, and by U.S. participants led by UT Austin. The programs are designed to better prepare secondary students for a technology- and knowledge-driven economy, to equip secondary teachers for teaching and learning in a technopolis, to encourage entrepreneurial thinking and research-driven innovation among university faculty, students, and staff, and to create the kind of coordinated and collegial assistance among all participants that comes from “social capital, networking and intermediary activity” (Cooke, 2001, p. 31). Cooke was writing about interactions between industrial firms (industry) and scientific organizations, but as used here, the meaning is extended to include the relationship between secondary schools and the HGIC sectors. Actors in the region must grow that relationship. It must be a robust relationship, if the region is to create an innovation culture, build a knowledge workforce, and grow its emerging technology- and knowledge-driven economy over time.

Medellín's Science (Ciencia), Technology and Innovation (CTI) Plan

The StemDev Medellín efforts are proceeding within the context of the city’s science and technology plan. A key element of that plan was the creation of an organization responsible for developing knowledge businesses (Echeverri, 2014). The organization is called Ruta N (branded *Ruta^{n}*). The Spanish word Ruta means *route*, N means *norte* (north), and Ruta N evokes for *Paisas* (local citizens) the positive transformation of Medellín, with a focus on benefiting the less economically secure citizens of the region. Ruta N is built on seminal concepts of creative destruction and industry clusters as developed respectively by Schumpeter and Porter.

The “Medellín 2021” (Echeverri, 2014, p. 2) vision will be actualized in the short term by pursuing knowledge businesses, in the medium term by building innovation platforms, and in the long term by creating an innovation culture. Innovation platforms refer in part to university partners. UT Austin and the IC^2 Institute are acknowledged as two of the platforms/partners of the city. An “innovation district” (p. 37) has been designated and built in the city that includes Ruta N, Parque Explora, and a mix of education, cultural and business centers. The clusters of energy, health, and information and communications technology (ICT) are highlighted as targets for technology development; additional clusters are construction, fashion and tourism. Two large companies based in Medellín, Une (television/media) and EPM (energy/utilities) are noted as industry sponsors of the effort.

StemDev Medellín Short History

The StemDev Medellín program began in the fall of 2013 with an initial set of K-11 and technical university focused activities. For the city’s technical universities, innovation and technology transfer training was performed to assist the universities in developing an integrated research portfolio with commercialization potential. For K-11 and others, a symposium was held that integrated teacher professional development on PBL into a joint policymaker/practitioner event. This event was attended by approximately 130 people, including secondary teachers, university faculty, senior education administrators, senior and staff-level government officials, representatives from local industry, and leadership from local non-profits. A collective decision-making approach was deployed to determine priorities for 2014 efforts. A wide variety of interactions were encouraged and programmed to drive contact across all sectors. At the time of writing, a December 2014 symposium was scheduled to continue the series and continue collaborative decision-making through cross-sector efforts (Cooke, 2001; Gibson et al., 1992).

Program Principles, Key Theories, and Conceptual Models

The StemDev Medellín program is guided by a number of overarching ideas. These ideas unify the effort around best practices. They highlight considerations involved when transferring knowledge in international programs.

Principles

The program was established with a set of core principles. These principles were largely established early in the program. They were confirmed and revised through the 2013 symposium activities. In brief, these principles include:

- A think-and-do approach, integrating theory and action
- A complementary spirit of experimentation; trying ideas in Medellín context
- Embracing the concept of global citizenship (added during the 2013 symposium by consensus of the regional participants) in view of the history and culture of Medellín
- Emphasis on economic development and industry engagement
- Ongoing impact on practitioners and front-line managers, to create early wins
- Training conducted in the same way as advocated for teaching in schools (participant-centered, project-based, interactive)
- Graying of silos through building of connections
- Modeling and mentorship
- Leveraging compatible activities already underway in the community
- Applying principles; not copying models

The principle *apply principles, do not copy* models is worthy of emphasis. This message is repeated constantly by the UT Austin team, and per the authors' observations, the principle has been embraced by the regional Medellín leadership, and repeated by them frequently to their peers and to local participants. Though not a rigorous research finding, it is clear to the authors that the regional leadership and participants hold one another accountable, as it relates to making sure they understand the principles at work. They are avoiding the shortcut of copying models that are proven only in other contexts.

Theory and models; modes of practice

- These five modes of practice are applied, consistent with the above principles.
- STEM/STEAM: Advancement of integrated STEM education. Furthermore, and more strictly, the region has focused fully on STEAM education, fully adopting the role of arts and humanities in program efforts.
- The technopolis model (Gibson et al., 1992), applied consistently to encourage regional cooperation.
- The Concerns-Based Adoption Model (CBAM) (Anderson, 1997; Hall & Hord, 1987), a theoretical model that highlights the steps in the process of changing teacher practice in classrooms.
- Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2008), a theoretical model that highlights challenges and techniques of integrating technology and pedagogy into inquiry-driven curricular content.
- Programs of Study (U.S. Department of Education Office of Vocational and Adult Education, 2010), a model for description of educational pathways and robust wraparound support services, made accessible to students, parents, and all stakeholders of the local education and workforce ecosystem.

Two Programs: Technical University and K-11

StemDev Medellín is organized into two programs, one for K-11 and one for the three technical universities that belong to the City of Medellín. The K-11 program is operated by Parque Explora, the city's science and technology museum. The technical universities program is operated by Sapiencia, a department of the City of Medellín.

Technical university programs with Sapiencia

Sapiencia is the higher education agency of the City of Medellín, recently formed to implement policy, provide coordination, and lead strategic projects in higher education. Sapiencia is building a technology transfer function for the city's three technical universities; is advancing innovation, entrepreneurship and technology transfer education for all students, faculty and staff; and is driving joint efforts with K-11 to better prepare students for colleges focused on a knowledge economy. In the 2014 program, approximately twenty faculty and staff members participated in a course that teaches techniques for rapid analysis of university technologies with commercialization potential. The program also included direct services in early market research, technology portfolio development, portfolio platform development, and entrepreneurial education. The detailed list of activities included:

- Portfolio development efforts using the RapidScreen™ early commercialization analysis platform; certification of local RapidScreen mentors.
- Quicklook®[2] Methodology Training, a 15-day course on early market engagement, with additional elements of technology transfer office strategy, value chain analysis, and technology surveillance with university R&D groups, using live cases from the universities.
- Direct early outreach to U.S. industry regarding technologies in the Quicklook® training.
- Instructional design of an innovation, entrepreneurship and technology transfer course for students, faculty and staff at the technical universities, with potential future adaptation for older K-11 students.
- Technical assistance on development of workforce-driven K-11 models that provide early college credit and easy transition into college programs, following the model of Alamo Academies (Alamo Colleges, 2014).

Among the program outcomes to date are development of a 55-technology portfolio, ongoing Quicklook® Methodology-driven technology review of nine technologies, twelve students estimated to complete the full Quicklook® Methodology training, and as many as five students expected to achieve RapidScreen™ Mentor certification.

K-11 programs with Parque Explora: STEAM-LABS

Parque Explora, the city's science and technology museum, operates the StemDev Medellín K-11 program. The name of that program is STEAM-LABS 2014. As the name suggests, the program is organized around experimental development and deployment of STEAM projects in Medellín K-11 schools. Teacher teams develop the interventions using training and guidance provided by the STEAM-LABS instructors. To the maximum extent logistically possible, teams are mixed to include members from K-11, from technical universities, and from Parque Explora's teacher education team, MOVA. The K-11 schools represent a cross-section of Medellín's economic groups, and they are geographically dispersed throughout the city. During 2014, approximately 30 educators, mostly from K-11 but also from the technical universities, completed the STEAM-LABS training program and received certificates of completion from UT Austin and Medellín-based program sponsors. The goals of the STEAM-LABS program are as follows:

1. Increase the knowledge and skills of educators in Medellín regarding STEM and STEAM education. Include classrooms teachers and school Rectors in these efforts.
2. Position STEM and STEAM within the broad framework of global citizenship, and within the specific framework of regional economic development.
3. Train and support teachers in the development and implementation of PBL interventions within these frameworks.
4. Train teachers and students through these efforts.
5. Assess the efforts and prepare a 2015 plan that builds on efforts to date.

The program was conducted in six phases as described in Table 2.

2 Quicklook® is a U.S. registered trademark of The University of Texas at Austin.

Table 2: Phases of STEAM-LABS

Phase Name	Phase Description
Planning	Develop a detailed plan for the year.
Development Kick-off	Conduct a four-day workshop to introduce the process, and to train teachers and other STEAM-LABS stakeholders on PBL principles. STEAM-LABS teams begin experimental intervention development during the workshop.
Development Support	STEAM-LABS teams further develop their interventions. UT Austin team provides remote support.
Interventions Kick-off	Conduct a three-day workshop for additional training and to help teams complete their intervention development.
Interventions Support	The UT Austin team visits schools to observe implementation of STEAM-LABS projects in the classroom.
Symposium	Teacher teams and stakeholders gather to assess results and make plans for 2015.

Also, additional sessions were held to advance the industry connection goals of the program, and to build support with secondary school Rectors (Principals):

- Thirteen industry and professional association staff attended a *CreAccíon Team Workshop*, building employer and community support for the interventions.
- Three hours were spent with six staff members of the teacher professional development team from Parque Explora sharing lessons on running PBL programs.
- Two hours were spent in a workshop with approximately fifteen secondary school Rectors, led by a Principal (Rector) from a U.S. STEAM-focused high school.

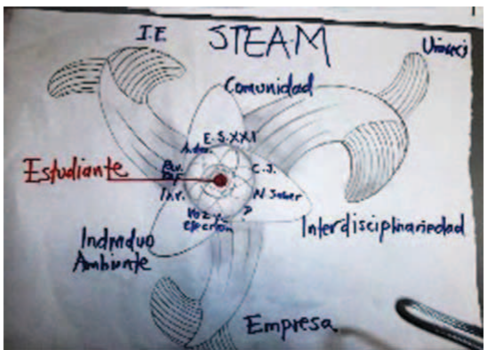
Key outcomes of the program were:

- Eleven experimental interventions were identified, designed, developed and deployed by joint secondary and university teams, with initial design support from MOVA educators.
- 31 educators across 11 teams received a certificate of program completion.
- 137 educators and 1,440 students were served by deployment of the interventions.
- 14 industry and community organizations supported development and deployment efforts.
- Participants formed a learning community through the program's online network.
- Evaluation identified successes to build on. Evaluation also identified challenges encountered during the process, and understanding of these challenges will help inform 2015 recommendations.
- Three extensive reports document in verbal and visual form the activities, outcomes, research data and implications of program execution.

CreAccíon Medellín Symposium, December 2013. Secondary education, higher education, government, industry community STEM and arts: Painting made and presented during symposium

Students present STEAM-LABS projects in their classrooms.

Teachers work at the Development Kick-off



STEAM-LABS Model created by teachers

Early STEAM-LABS Metrics and Research Results

For the purpose of identifying confirming or de-confirming evidence regarding conceptual areas for the StemDev Actor Perceptions Instrument, this section of the paper outlines metrics and early research results from the STEAM-LABS 2014 effort. In the future, a separate paper is planned that will provide a more complete report of results. It should be noted that the primary purpose of the efforts described were formative; in other words, they were to assist the ongoing, experimental process of the interventions, in a manner consistent with the spirit of Design-Based Research (Barab & Squire, 2004). Results are offered acknowledging the substantial involvement of the authors on the ground in research activities. Nevertheless, these results can prove useful as a point of comparison for the promising conceptual areas of the proposed instrument.

Description of Projects

Table 3 lists the 2014 STEAM-LABS projects. Teacher teams were provided with eleven sample PBL projects that aligned with one or more of the Medellín science and technology plan focal areas of health, energy, or ICT. Teachers could use these sample projects as a starting point, or they could create their own projects based on one or more of the three industry focal areas. Recall that some educator teams included university faculty.

Table 3: 2014 STEAM-LABS Projects

School	Project Description
San Antonio de Prado Colegio Cooperativo	Developing video games that teach about health.
Colegio Loyola Para la Ciencia y la Innovación	Developing more resource efficient consumer goods and systems for daily use such as cooking, cleaning, water usage, etc.
Colegio Loyola Para la Ciencia y la Innovación	Using robotics to teach mathematics and Cartesian coordinates.
Concejo De Medellin	Conducting an energy audit to reduce carbon footprint.
Colegio Gimnasio Los Pinares	Developing renewable energy resources for rural hotels.
IE Guadalupe	Creating original digital images inspired by natural life forms, for use in advertising.
INEM José Félix de Restrepo	Developing an educational game to analyze and use Colombian football statistics.
Instituto Técnico Industrial Pascual Bravo	Developing innovation projects using rigorous methodology to address local challenges.
IE José Acevedo y Gómez	Recycling and reusing organic and inorganic waste products in consumer goods.
IE José Maria Bernal	Developing student projects regarding making good education and career choices.
Pbro Antonio José Bernal Londoño	Conducting student research projects related to real world technical and social problems and applied mathematics.
Sol de Oriente	Improving the production, use and transport of energy.

Projects were highly interdisciplinary and grounded in local concerns important and motivating to students. Many of these issues are also concerns of global citizens.

Teacher perceptions of appropriateness of content

Participants in the two main, on-site training sessions completed a survey regarding the value and quality of the training. There were in excess of twenty respondents to each survey. The ratings shown in Table 4 indicate they found the content appropriate and useful. The content was based on Buck Institute for Education materials (Markham et al., 2013) that advocated significant-to-students content relevant to academic subjects, 21st century skills, in-depth inquiry, driving questions of interest to students, voice and choice for students, critique and revision, and a public audience (Buck Institute for Education, 2014).

It must be noted that teachers in the 2014 program came with meaningful prior experience in project-based learning. However, teachers had minimal experience with the Buck Institute for Education model, and with some of its core principles, especially those related to rigorous academic content and intentional interdisciplinary integration. Results suggest that there were specific areas where teachers learned new content, despite prior experience. The teachers' prior experience should be considered when interpreting results.

Table 4: Average of Ratings, Development and Interventions Kick-offs

Question	Rating (1–5, 5 best)	Question	Rating (1–5, 5 best)
Information was new to me	4.56	Structure	4.65
Appropriate to needs	4.63	Improving your skills	4.52
Instructor knowledge	4.87	Effectiveness enhanced	4.55
Able to use in classroom	4.74	Overall rating	4.69
Instructor communication	4.88		

Coverage of disciplines and industry clusters

Tables 5 and 6 shed light on the degree to which different teaching disciplines were covered in the program. There was relatively even coverage across disciplinary areas and clusters. There were fewer math teachers, and fewer projects focused fully on health, but a significant number nevertheless. Note the inclusion of a small but meaningful number of language and art teachers.

Table 5: Teachers Served by Subject*

Subject Area	Number of Teachers Served**
Technology	9
Science	10
Mathematics	4
Language (Spanish)	3
Art	1
Other	13
Total	40***

*Eight technical university faculty members fully participated in completed projects.
**As self-reported by the teachers.
***Not all teachers served in the program completed the full program to earn their certificate.

Table 6: Projects by Topic and Grade

BY TOPIC Number targeted	Main topic	Main or secondary	BY GRADE Number targeted	
Health	2	3	5th	1
Energy	4	6	6th	3
ICT	6	7	7th	4
			8th	4
			9th	3
			10th	4
TOTAL PROJECTS	12		11th	5

Grade level coverage.

The summary of grade level coverage in Table 7 shows relatively even participation of students between 6th and 11th grade, or at least no obvious pattern in the variation. The participation of university students as mentors is noted.

Post-training challenges survey

After training, a Likert-scaled survey was distributed asking participants to rate the difficulty of different challenges. Time for teacher collaboration and planning was rated as the greatest overall challenge. In addition, making industry connections, incorporating rigorous content, gaining access to tools and materials, and creating teacher and student collaboration cultures also rated as challenging for most groups.

Table 7: Grade Level Coverage

Grade level	Number of Students Served
6^{th}	268
7^{th}	168
8^{th}	183
9^{th}	301
10^{th}	240
11^{th}	280
University (served as mentors)	37
Total students (6–11)	1440

Teacher concerns through the project

A survey inspired by the Concerns-Based Adoption Model (Hall & Hord, 1987) revealed that most teachers settled into their PBL projects as they progressed. Early in the project, a number of teachers either (1) held significant concerns, or (2) they felt they already understood PBL. As the project progressed, both those early in the adoption curve (with concerns about PBL) or later in the adoption curve (feeling they already knew PBL) shifted toward the middle of the adoption curve. In other words, most teachers came to view their learning of the STEAM-LABS content as a work in progress. Figure 1's word cloud for a related open-ended question shows that teaching and learning, method and process, and relationship to college and work preparation were significant concepts for participants.

Figure 1. Word cloud of training concepts

Teacher integration of technology and projects into the classroom.

The TPACK theoretical model (Mishra & Koehler, 2008) was the inspiration for survey questions related to teachers grasping the importance of fully integrating technology, pedagogy and rigorous content. The model predicts that teachers will be challenged by this integration, perhaps underestimating its difficulty. This tended to be confirmed by the data collected to date. A typical paradox was present, of teachers feeling more comfortable with the pedagogy, yet reporting less confidence in their ability to integrate the three TPACK elements, as shown in Table 8.

Table 8: TPACK Survey Results: Biggest Movers

The 2 of 9 categories showing the greatest change between the first and second survey. (Respondents chose up to three of the nine statements offered that best reflected their current standing related to PBL.)

TPACK-driven question	May	July
I am capable with PBL pedagogy.	31 %	52 %
I am certain I can combine technology, pedagogy and content, to drive rigorous learning.	23 %	0 %

Context offered by industry and community organizations

In addition to the results reported above regarding the difficulty of industry engagement, reports were also common regarding the contextual value brought by industry. This included creating new meaning for students regarding the relevance of STEM fields, the validation for students and teachers offered by industry's presence in the program, and the value of project design advice to make the projects more real for students. Joining industry were various community organizations who brought an advocacy and global citizenship perspective to important regional concerns.

End of project school visits: Keep helping, keep building networks

During end-of-project visits to the schools to observe the projects in action and talk with participants, it was clear that continued assistance was a priority. This information came in three forms: (1) teachers asking directly for continued assistance; (2) teachers commenting on the value of seeing the work of teaching colleagues at other schools; (3) Rectors noting the value of validation (through these end-of-project visits), and their requesting continued assistance.

Student feedback

While the team interacted with secondary students during end-of-project school visits, secondary student feedback was not formally collected during the first year of STEAM-LABS. A future addition to the program might include student-targeted instruments designed to evaluate the effectiveness and engagement quality of classroom projects and methodologies. Such instruments might be delivered to students both before and after teachers apply their STEAM-LABS training in classrooms. In addition, the proposed StemDev Actor Perceptions Instrument might be adapted in future versions to also work for students.

Analysis

Table 9 repeats the content from Table 1, *Promising Conceptual Areas for Constructs, Based on Literature.* Rather than cross-matching to literature citations, the table now notes areas of confirming or de-confirming evidence based on STEAM-LABS 2014 metrics and early research results. In summary, all conceptual areas receive some confirmation. The strongest de-confirming observation is that teachers crave continued contact with other teachers. Such activity is intra-sector and would tend to shift focus away from cross-sector activities. Viewed through a different lens, however, one might identify a desire for a *teaching technopolis,* and note that the grounding in the needs of the Medellín community has been the foundation for building this teacher community. It is also noted that de-confirming evidence may simply highlight areas where perceptions differ between actors. All comments should be considered while remembering that the 2014 educator cohort had a relatively high amount of prior experience with PBL.

Table 9: Promising Conceptual Areas for Constructs, Viewed through STEAM-LABS 2014

Conceptual area	Confirming results • Bullet items: de-confirming or alternatives
Economic development	
Regional economic development	Descriptions of projects are grounded in community needs. Industry engagement is welcome and sought out.
Technology-driven economies	Same as prior. • Integrating technology in the classroom is not simple.
Regional industry clusters	Same as prior. • It is not simple to engage industry.
Regional technology-driven economic development plan	The regional plan served as a framework for identifying projects, and was embraced.
Higher education's role in economic development	Most higher education faculty embraced their role on the team. Some were the conduit for industry connections.
Secondary education's role in economic development	Some industry actors embraced the projects. • Engaging industry across the board was difficult.

STEM education	
STEM education as a concept	STEAM education was embraced as demonstrated by teacher perceptions of appropriateness of content, coverage of disciplines, coverage of industry clusters, and grade level coverage. • In Medellín, STEAM, not STEM
Public literacy in STEM education	Project descriptions and success of projects suggest STEM literacy is a topic of interest.
STEM's presence in colleges and universities	The engagement of university faculty suggests STEM is desired and expertise exists. Focus on integration is welcome.
STEM's presence in secondary schools	Knowledge of the teachers and CBAM findings indicate STEM and PBL are already in some schools. Project evaluations and success in deployment tends to confirm.
Interdisciplinary application of STEM	Descriptions of projects indicate all projects were interdisciplinary • Integration across subjects is difficult, as indicated by TPACK findings.
Rigorous academic content in STEM	Team objectives demonstrated integration. • This was reported as a more challenging topic in the program. TPACK findings tend to confirm.
Authentic content based on real-world concerns and/or global citizenship	Descriptions of projects support feasibility of this approach. Metrics of teachers and students engaged support this concept.
21^{st} century skills in STEM	Classroom observation and student presentations showed some students leading, team building, communicating.
Integration with arts and humanities disciplines	Numerous project descriptions indicate graphics or creative components; real-world context required storytelling. • Majority focus was on STEM subjects.
Focus on early STEM foundations in pre-teen students	Not studied in this project. However, metrics show even support down to sixth grade, which might include the oldest pre-teens.
Teacher capacity to deliver using STEM-compatible pedagogy	Success indicate teachers can deliver. • TPACK indicates challenges in integrating technology, pedagogy, content.

STEM and Regional Economic Development Alignment	
STEM program alignment with regional technology-driven economic development plan, in higher education	Teachers readily developed content based on the three plan-compatible industry clusters.
STEM program alignment with regional technology-driven economic development plan, in secondary education	Framing consistent with the city's science and technology plan appeared to motivate teachers and students.
Role of higher education in secondary STEM education	The participation of eight technical university faculty members confirms interest through the commitment of their time.
Role of community partners in secondary STEM education	Community partners' missions align with projects in classrooms; those partners bring additional context.
Industry engagement with higher education STEM programs	At times, university faculty were the conduit for industry connections.
Industry engagement with secondary education STEM programs, for example, through speaker's bureau, curriculum advice, real-world content, intermittent funding, program volunteers, mentors, internships, scholarships, sustained funding.	There was meaningful engagement of industry partners. • This was reported as one of the more challenging aspects of the program.
Regional career promotion	One project, IE José Maria Bernal, directly addressed career promotion. (This project served a high number of students.)
Regional pathways and programs of study	This topic was not directly studied in STEAM-LABS. (It is more directly addressed in the Sapiencia program.)
Regional champions who work across boundaries	While not a direct topic of research, this project fundamentally required cross-sector work and would not have happened without first and second level influencers (Gibson et al., 2013). • Many challenges reported connecting secondary education to industry.
Regional executive champions who enable cross-sector activities	Same as prior.

Proposed Process for Instrument Development

The literature review and early StemDev Medellín results review intentionally focused on *conceptual areas* that may be of interest in development of the StemDev Actor Perceptions Instrument. To create an instrument, it now will be necessary to create provisional questions, test those questions, and use the questions in initial studies. The instrument must be available in the native language of the desired respondents. This is the future work proposed by this paper. Following a recap of the instrument's purpose, a brief summary is offered below of proposed phases for development. These phases include question development, initial testing for constructs and reliability, and revisions that lead to an instrument with valid results for its early populations, including actors in Medellín.

Question Development

The authors argue that the literature review and early research results offer a significant platform from which to begin question development. The conceptual areas identified will be translated into questions separately by two researchers knowledgeable in the fields of interest. Then the questions will be compared, individually re-worked, and compared again, etc. This process will follow the spirit of constant comparative coding (Saldaña, 2009), while applying that spirit to a process that cannot be strictly described as emergent or theory-constrained coding. On agreement of the question developers, the survey will be taken by five other colleagues who represent secondary education, higher education, government, industry and community organizations. After taking the survey, their input into the instrument will be solicited through a second survey, seeking information on clarity of questions, missing questions, and other comments as offered. The original two question developers will then re-engage in development and discussion until a provisional instrument is complete.

Testing for Constructs and Reliability

The provisional instrument will be deployed with at least thirty participants from secondary education, and thirty participants from other HGIC sectors. Formal methods for developing reliable and valid instruments will be deployed (Fraenkel, Wallen, & Hyun, 2012; DeVellis, 2012), including a search for potential constructs and their reliability and discriminant validity. The original two question developers will review results and re-enter a process of question revision. Efforts will be made to define clear constructs while also simplifying the instrument and removing questions that do not contribute to essential outcomes. The instrument will then be re-deployed with new participants from the same region, with constructs evaluated, reliability measured, and discriminant validity measured.

Instrument Completion

The process will continue until the instrument is judged to have shown reliability and validity in at least one population. The author's intent is then to publish results. The instrument will be made available as one tool for measuring the alignment of STEM education with economic development in regions.

Conclusion and Next Steps

This paper has proposed development of an instrument to help regions measure the integration of their STEM education efforts with their regional economic development goals. The *StemDev Actor Perceptions Instrument* will measure the degree to which regions are organizing between secondary education, and higher education, government, industry and community (HGIC) sectors, from the perspective of actors in the system. It will be primarily concerned with the mutual perceptions of secondary education vs. the HGIC sectors. Twenty-seven *conceptual areas* within the broad categories of regional economic development, STEM education, and STEM-economic development alignment were identified from literature, and then analyzed against StemDev Medellín's early research outcomes.

In the process, the StemDev Medellín program was described. That program is offering training in university technology transfer and entrepreneurial education, and in secondary STEM education using project-based learning. The program also intentionally aligns activities across sectors, framed by Medellín's plan for science and technology, and by its three priority industry clusters of health, energy and ICT. Early results from this program were used as a lens for further analysis of the conceptual areas identified in the literature review.

The findings of this study should be considered within its limits. The authors have led this and previous programs, and they arrive with a bias toward the importance of cross-sector activity in a region. The StemDev Medellín research is primarily formative, targeted at program operation through an experimental application of principles, with these principles extracted from models with a prior history of success. The Design-Based Research (Barab & Squire, 2004) approach means that the authors are not maintaining independence in the study, and are in fact fully engaged in the effort. The educators in the first STEAM-LABS cohort had prior PBL experience and likely does not represent an average teacher in the Medellín region. Quantitative findings were shared, but they were descriptive (mostly metrics) and not amenable to rigorous quantitative analysis.

Economic development is not the only concern of innovation. In a growing and vibrant region like Medellín, Colombia, with a rich Paisa heritage and culture, innovation refers to arts, culture, social advancement, and any other endeavor that improves quality of life for citizens. Technology-driven economics serves the goals of the region, not the reverse. Applied in the correct way—applied as a tool—technology-driven economic development builds knowledge in regions and offers great promise to improve the lives of those regions' citizens.

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