Knowledge infrastructure and regional growth

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1. Introduction

In the regional growth literature, the strategic relevance of knowledge for innovation is increasingly recognized. Already in a neoclassical analysis framework, long-range factors, such as education, R&D, and technology, played a critical structural role in the context of the spatial mobility of production factors which could remove disparities (e.g. in terms of per capita income) in the long run and, as a result, equalize factor productivity in all regions (Capello and Nijkamp, 2009). In the field of endogenous growth, Krugman's efforts have led to a greater emphasis on knowledge as a driving force for development and even on the endogenous self-reinforcing mechanisms of knowledge creation. In macroeconomic models of endogenous growth, technological progress is mainly an endogenous process in an economic system, where knowledge is generally embedded in human capital (Romer, 1986; Lucas, 1988). In this way, regional growth is not the result of exogenous productivity-enhancing factors but rather is the result of deliberate choices of individual actors (firms and policy makers). Spatial spillovers, i.e. locally bounded and territorially rooted interactions among actors, institutions and local economies, are in this regard also widely studied in the regional economics and economic geography literature as they explain how knowledge externalities spread around. Spatial spillovers represent pure externalities, producing non-compensated advantages for receivers. A discrepancy between private and social optimum creates the emergence for ad hoc policy interventions (Capello, 2009).

As spatial distribution of knowledge and its spillovers are considered important success factors, and geographical patterns of knowledge diffusion, as well as the barriers to access knowledge, are decisive for regional development, knowledge policy is a critical success factor for regional welfare creation (see, e.g. Acs et al., 2002; Döring and Schnellenback, 2006; and Keeble and Wilkinson, 1999). Knowledge, here, refers to education, learning, training, creativeness, and R&D. In the current times of economic recession, more than ever, government has a role in focusing strong, directed efforts to boost the translation of scientific ideas into useful technologies, and to reinforce the base of science skills that drives this innovation. In a current article in Nature, Ian Taylor (2009) refers to the ability to capture ideas and discoveries that flow from research as the main test of whether the UK can recover growth and prosperity. According to Taylor, at present, the UK does not have the workforce needed to enact new technologies to address issues like climate-change and diversity of energy supply. This is applicable to other countries as well. Increasingly, initiatives are undertaken at local, national and international level. Current initiatives cover many domains, but approaches often are too fragmented and have too little scope and mass. Countries are as a result exposed to risk by not producing enough domestic talent. Also, other parts of the world outside the USA (e.g. Japan, Korea, China, India) are stepping up their efforts and investments in research and development. These processes will finally result in strong emerging science nations like China and India, which will compete for the best people and make it more attractive for their citizens to perform sophisticated research domestically.

The current global challenges including the current economic crisis, climate change, poverty, health, and food and water shortages, require well-equipped science-systems that work well on both a national and an international level. A recession creates opportunities on a national level, as it is a great time to increase recruitment into science study and reverse the outflow of graduates from careers in science. Society is critically dependent on advancements in science and technology and needs talented people to carry knowledge forward. As a result of global competition in as well as outside the science domain, on a regional level, there is an imbalanced outflow of talent with many researchers seeking for a research career in the USA. On a global level, the current crisis can act as an opportunity for positive change that leads to new, global common values. The move towards collective interest, however, requires an understanding of socioeconomic, political, psychological, historical and legal trends. A changing socio-political environment will need different research disciplines to work together more than ever (Hertz, 2009). Currently, there are different forces at play in the science domain that need attention and support from governments. Besides tensions between national and international demands, the current crisis has highlighted the growing frictions between the individual and societal needs. In the present paper, we aim to frame these movements in the science community in order to examine the causes of the recent frictions and provide policy solutions.

After a general overview of the effects of globalization and the current economic crisis on the research domain society as a whole, the benefits of knowledge for economic growth will be further explained by means of literature research. Having defined the changing economic landscape and the increasing importance of knowledge therein, next, a first attempt will be made to introduce scenarios as a guiding framework for national governments to map out possible changes in the activity of the research community and what effect they may have on economic growth and welfare in the broader sense. The knowledge and spillover literature from regional economics and economic geography will be used as a guiding principle. Scenarios explore the future by consistently working out different lines of thought, which makes it easier for policy makers to respond in a consistent way to future uncertainties.

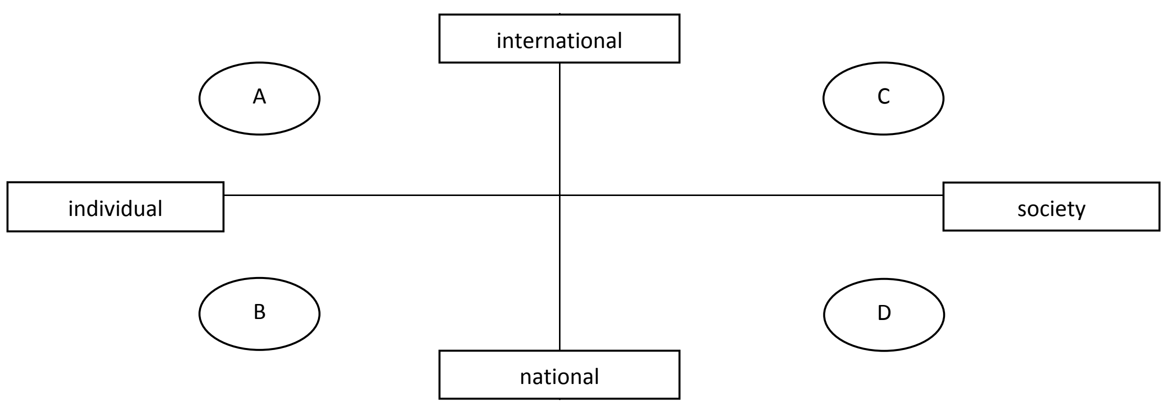
2. Research at a crossroads

When hard times hit, a rebalancing of economic activity is vital for recovery. In the past, this has caused research budgets to shrink, although the US New Deal programme of the 1930s and the Japanese 'five year plan' for science and technology after the 1990s financial crisis serve as successful exceptions to the rule. National programmes that established a new era in government-science relations, with expanded funding for basic research and national research efforts to support goals such as resource conservation and public health. Today's crisis is different insofar that global challenges are becoming more pressing. Revolutionizing transport technologies, meeting climate-change targets and securing diversity of energy supply are key problems of both national and international interest. On a national level, this requires more directed research, and more courses to teach these skills, which are necessary to create a workforce able to enact these technologies. The active participation of industry in government-science relations is hereby essential to help encourage innovation. Applied research should be raised to the status of basic science, and collaboration and creative engineering should be encouraged.

This crisis also provides global opportunity. During the Great Depression, the values of compassion, sharing and social justice became [more] dominant than they had ever been before in American history (McElvaine, 1993). The current global depression may also show a movement away from self-interest towards further cooperation. Different from previous crises, the current global challenges require a sense of community that stretches beyond local and national borders. To tackle these problems, the research domain needs a more global view. This, in turn, requires commitments from national governments that will allow the research communities to better compete, collaborate and thrive internationally. For example, research grants should be made more accessible for international research projects. Students and younger researchers should be encouraged to go abroad for a period of study or for their early career, to improve their international networking. Also, universities and research institutions should become more open and attractive to the outside world.

High quality research depends on many factors next to the human brain factor: the presence of good scientific infrastructure and facilities, the provision of sufficient and well allocated funding and adequate funding instruments, excellent access to information, a favourable social capital, good possibilities for exchange and interaction, attractive career structures, clear and visible leaders, etc. Together, all such factors determine the attractiveness and quality of the operating context for researchers, thus constituting what we could call an attractive research climate. It is this climate which provides – and crucially sometimes fails to provide – opportunities for people to perform qualitatively good research. In order to create an attractive research climate, a wide range of opportunities needs to be generated, for example by generous funding and appropriate career structures, by freedom and responsibility for talented young researchers to choose and direct their own research, by the possibility to address challenging, novel issues, to address high risk research topics and by access to world-class facilities.

The more and better opportunities are created, the more the science domain will succeed in retaining and attracting talented people, resulting in a higher quality of research in science and technology, which is key to a successful economy and society. However, in order to achieve this goal, important improvements are still necessary in a number of critical aspects. To give an idea of the current developments in the science domain and its effects on society, we will make a first attempt at mapping out four illustrative scenarios (for details see Nijkamp et al. 1998; Nijkamp et al. 2005). Here, scenario thinking is used in the form of a structured brainstorming technique with the idea to help to widen the perceptions of researchers and policymakers regarding future possibilities and their impact, while at the same time better structuring their current knowledge of the science community and its working. This does not imply that the future will resemble any one of the scenarios, but rather will most likely include aspects of all of them. The model in Figure 1 consists of two intersected variables, of which each of the four resulting quadrants is treated as a possible future. Here we may visualize that further internationalization of the science domain will go together with a high level of collective interest. At the same time, this cannot be achieved with a strong national focus and attention for the possibilities for the individual researcher.



A. Mobility
B. Learning
C. Spillovers
D. Triple-helix

Figure 1 Illustrative forces in the science domain

3. Research bottlenecks and opportunities

On the basis of Figure 1 in the previous section, bottlenecks and opportunities can be visualized in the research domain based on four scenarios that may be either national or international by character, and that focus on the individual or rather on the societal needs. In this section, the four scenarios will be discussed in more detail. Regional economics and economic geography literature on knowledge, spatial spillover effects and regional growth will be used as a guiding principle here.

A. Regional receptivity

The upper left quadrant represents a movement towards greater regional receptivity in the science domain. Growth spillover effects at regional level highly depend on regional receptivity, which is defined as the capacity of a region to extract the highest benefit from access to information, knowledge, services and other places in general. This means that the capabilities of individual economic agents to exploit spillovers highly depend on strong territorialized imitable and un-imitable assets, so besides pure availiablity of capital, presence of skilled labour force, and pure accessibility there also needs to be a strong focus on local trust and sense of belonging, creativity, and connectivity (Capello, 2009). From a knowledge perspective, regional receptivity can be improved by stimulating mobility of researchers. (International) mobility of researchers is vital for broadcasting ideas and enhancing creativity. Still many barriers to mobility exist, thus impairing the inflow and exchange of highly skilled workers. Complicated and prohibitive legal, administrative and entry regulations obstruct free entry to research opportunities and prevent exchange of scientists and scientific ideas. Diminishing (or removing) barriers offers great potential benefits to the careers of researchers and to their research efforts. Countries need to improve mobility both inside and outside their borders on a larger scale. Furthermore, negative financial implications for researchers (e.g. the lack of pension portability) unnecessarily inhibit mobility.

B. Learning

Individual learning is central in the lower left quadrant. This scenario is associated with the ideas of the learning environment (Storper, 1997), where the daily access to the relevant resources (information, knowledge, technology, ideas, training and skills) are activated through the networks of interdependency and common understanding that surrounds a region’s actors (individuals, firms, institutions). The region itself now represents a critical source of development, and “a key, necessary element in the ‘supply architecture’ for learning and innovation” (Storper, 1995). For a region to become successful then, an attractive knowledge infrastructure should be in place. From a knowledge perspective, such an infrastructure is still often lacking. Positions in the science and knowledge domain often lack enough attractiveness in terms of career opportunities for talented people (unclear perspectives, lack of autonomy) and labour market status (worse job conditions and social provisions than positions outside academia). Attracting young people starts with good doctoral education (high quality, open structure, professional supervision, competitiveness with other sectors in the labour market). Subsequently, attractive conditions exist if talented young people have the opportunity to build their career and leadership profile, in academia, but also in industry. Furthermore, adequate funding providing greater autonomy to individual investigators is still in short supply, whereas progress towards the creation of a better career structure, e.g. tenure track systems, is slow.

C. Growth spillovers

This scenario refers to the most general concept of spillovers in the literature: namely, the one of growth spillovers (Arora and Vamvakidis, 2005; Holod and Reed, 2004; Cheshire, 1995; Cheshire and Carbonaro, 1996). Growth spillovers represent the broadest of spillovers, i.e. represent a situation in which a region grows, thanks to the behavior of neighbouring regions. A region is a geographically limited economic system, where it is rarely the case that all necessary good are produced locally or exceed local demand when produced locally. Trade linkages are necessary for the survival and growth of the regional economic system. The same applies to knowledge production. The international level is required to act with respect to conditions which impact the broader aspects of pursuing careers in science and technology. Such conditions concern especially mobility, European-wide supporting frameworks (e.g. for patenting), efforts concerning large, European-wide research endeavours (big science facilities, trans-European networks, certain domains of science, e.g. climate issues), etc. Joint efforts can exploit opportunities offered by the scale of the global economy, while complementing local and national efforts. The endeavour of the European Research Area (ERA) is a relatively young, but important new initiative in this respect which can provide an answer to various challenges in the domain of European research, provided it offers the right solutions to the right selection of problems, i.e., if it delivers benefits that are not otherwise accessible to its member states and if it supports common needs and exploits the opportunities of scale.

D. Triple helix

Finally, the triple-helix scenario particularly highlights the need for further cooperation on a national level between science, government and industry. This concept stems primarily from the economic geography literature on localized knowledge spillovers. According to this strand of literature, knowledge is a tacit and primarily local public good (Krugman, 1991, 1995, 1996; Krugman and Venables, 1996). Innovation inputs (from private R&D or university research) according to this approach, lead to a greater innovation output when they originate from local sources, i.e. from firms and public institutes that are located in the same region. Etzkowitz and Leydesdorff (1996, 1997, 2000) in this regard developed the triple helix model, which affirms the existence of a spiral pattern of relations and links between the three major institutional actors in a local environment: industry, university and government, in which the university tends to have a critical part to play the context of a knowledge-based economy. Overall, the intersectoral mobility between academia and industry is too low, damaging both economy and society. Better conformity to industry requirements in order to attract qualified researchers to work in industry is needed as well as an open bidirectional flow of researchers between industry and academia. Concentrations of outstanding scientific facilities and activities are very important to create challenging and attractive working conditions and opportunities for talented people. Such (trans-disciplinary) centres foster high quality of research through the larger scale of competition and greater possibilities, which form the seedbed for creative thinking. Also contributing to the enhancement of the attractiveness of research is the facilitation of access to and the use of (new) technologies and sophisticated research infrastructure facilities.

In Figure 2, several of the most important challenges and opportunities in the research domain are visualized.

A. Regional receptivity Mobility of researchers Legal, administrative and entry regulations Negative financial implications	**C. Growth spillovers** Cross-border research Supporting frameworks (e.g. for patenting) International research networks
B. Learning Labour market status Good doctoral education Greater autonomy to individual researcher Tenure track system	**D. Triple helix** Research infrastructure facilities Interdisciplinary research centers Facilitation and access (new) technologies Technology transfer

Figure 2 Opportunities in the science domain based on the four illustrative forces

4. Ways forward

The current economic crisis asks for a reconsideration of national investments and increasing global challenges for an increasing focus on international cooperation. National governments cannot rely on the formerly dynamic financial services sector as the engine of growth, which makes a rebalancing of economic activity vital. This will in many cases lead to a refocus of spending on innovation into areas of national interest. Science and technology are a key factor in the process of innovation. Funding in these areas should therefore be protected. Not least, because science and technology also play a leading role in tackling the global challenges. A healthy national and international research climate is therefore essential. As mentioned above, significant improvements have to be made in various core domains in order to remedy the research domain's main weaknesses. In this section, several improvements will be discussed for the four dominant research scenarios[1].

Scenario A: Improve the inflow and exchange of qualified people

Create critical mass in terms of increasing the opportunities of research grants and positions which contribute to the independent career of the best scientists. Stimulate the opening up of national regulations and programmes in order to enable portability of and access to research opportunities and grants. This implies running down formal and informal barriers which form impediments for highly skilled knowledge workers (e.g. legal issues concerning visa, job security, pensions, etc.).

Scenario B: Improve the career perspectives for (young) researchers

There is a great need to establish better career paths for researchers and to attract young people to a science career. A number of things are needed in this domain: improvements in the structure of doctoral education in order to increase the quality and attractiveness for young people to pursue careers in science and technology. Improvements include better structure of education (not only at the tertiary level; conditions at the secondary level have to be improved to, in order to create interest in pursuing science careers), as well as better coordination across systems (enhancing exchange possibilities). The most talented young researchers need to have a clear career perspective, and a system of tenure track has to be put in place. The career perspective should also involve the opportunity to establish a group and/or laboratories under their leadership. Funding of different sources (research councils, ministries) has to be adapted to support suitable career paths for young researchers. Experiences at many levels show that granting career and research autonomy improves both quality of research as well as science career opportunities and science career attractiveness. Therefore, funding instruments which support this have to be developed and stimulated.

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[1] **Selected list of relevant documents**
-Academy of Finland: Methods for Evaluating the Impact of Basic Research Funding, Helsinki, 2006
-ALLEA: Challenging of the Future: Reflections of ALLEA on ERA, 2007
-EC Green Paper "The European Research Area: New Perspectives", 2007
-EUA: Doctoral Programmes in Europe's Universities: Achievements and Challenges, 2007
-EUA: Lisbon Declaration. Europe's Universities beyond 2010: Diversity with a Common Purpose, 2007
-EURAB: Increasing the Attractiveness of Science, Engineering & Technology Careers, 2007
-EUROHORCs-ESF response to the Commission Green paper, 2007
-ESLF: Careers in the Life Sciences, 2003
-LERU: Universities and Innovation: the challenge for Europe, 2006
-LERU: The Future of the European Research Area, 2007
-Research Councils UK, Excellence with Impact, Swindon, 2007

Scenario C: Exploit the international research scale

Using the larger scale especially applies to the area of investments in expensive facilities and scientific infrastructure. Such facilities are important, as they drive science forward at the edges through fundamental discoveries, but they also attract talented people and foster innovative research, thus creating a dynamic and inspiring environment for people to work in. The formation of research concentrations should be driven forward by, for example, coordinating the provision and the development of funding of major, expensive infrastructure. The European Strategy for Research Infrastructure (ESFRI) can offer an effective means to engage the relevant research communities in developing initiatives and agenda setting, but this has to be followed up by national and local initiatives.

Scenario D: Improve university-industry-government interactions

There is a need for better conformity to industry requirements in order to attract qualified researchers to work in industry is needed as well as an open bidirectional flow of researchers between industry and academia. Also, the portability of granting instruments between universities, industry and countries should be allow/increase without bureaucratic or financial obstacles (i.e. implementation of the principle of money follows researcher, but also practical solutions to social security portability).

Table 1 Bottlenecks and solution directions of the four research scenarios

Scenario	Bottlenecks	Solution Strategies
A.	Mobility of researchers Entry regulations Financial implications	Increasing the opportunities of research grants and positions Opening up of national regulations and programmes Running down formal and informal barriers
B.	Labour market status Doctoral education Career opportunities	Improvements in the structure of doctoral education A system of tenure track Funding instruments which support this have to be developed and Stimulated to allow granting Career and research autonomy
C.	Cross-border research Research conditions Supporting frameworks	Investments in expensive facilities and scientific infrastructure Formation of research concentrations
D.	Infrastructure facilities Research centers (New) technologies Technology transfer	Better conformity to industry requirements as well as an open Bidirectional flow of researchers between industry and academia Allow/increase the portability of granting instruments between Universities, industry and countries

5. Epilogue

Society at large needs and deserves an attractive research environment, not only for scientific reasons (important as these are), but also for economic and societal reasons. The advancement of human knowledge through the development of intellectual capital – in particular, the development and acquisition of skills through innovative research support systems – is a sine qua non for a healthy future. Excellent knowledge will create favourable benefits in the business and commercial sector and for society at large. It will also enhance our opportunities to improve quality of life (e.g., environmental protection, health schemes, social integration, cultural advances), while it will favour balanced policy-making in the public and private sector as well. That is why highly innovative, novel and frontier-shifting research is so badly needed. This will stimulate effective capacity building in new promising domains, lead to training and education of highly skilled people and develop new modi operandi for government and business. The value added of excellent research is invaluable. And society has the task to invest in the best it has, viz. scientific talent. The present scenarios have been helpful in localizing challenges in the research domain and suggesting improvements. However, equally important, more and better coordinated efforts in terms of communication and dialogue with society are required to promote the visibility and the attractiveness of European science.

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