Business science links for a new growth path

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It's research and teaching, stupid!

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Abstract

Policies towards business science links have been driven by the concept of the entrepreneurial university, i.e. encouraging universities to directly contribute to economic development through commercialization of their discoveries, e.g. through licensing of patents or start-ups, but also through collaborative R&D with firms. However, efforts to increase the entrepreneurship of universities have seldom targeted the first two missions of universities, research and teaching. Evidence shows that any entrepreneurship can only be as strong as the quality of research and teaching. Based on a conceptual model of universities' role in innovative activity and a review of the evidence, this paper has tried to argue that a narrow focus on linking universities with firms and society without making sure that universities' first two missions - research and teaching - work well is an ineffective approach towards increasing the contribution of universities to innovative activity, and hence to a new growth path. In particular, the role of training graduates is not stressed enough, while by far the biggest contribution of universities to innovative activities.

1. Introduction

In economies where knowledge is the most important production factor – or the one which allows for creating competitive advantage - non-firm knowledge-creating and -transmitting institutions such as universities and public research organizations play an ever increasing role. At the same time, societal challenges such as climate change and resource scarcity demand inter alia substantial scientific and technological progress, driven by efforts in basic and applied research. Against this background, governments have aimed at increasing the potential contribution of universities to economic growth and tackling societal challenges, both elements of a new growth path which combines economic dynamism with respect of environmental boundaries.

In the past, policies to improve the economic and societal impact of universities at the European level were guided by a diagnostic of a so-called “European Paradox” (see the Green Paper on Innovation, the Third Report on Science and Technology Indicators and a report on knowledge transfer, all by the European Commission, 1995, 2003 and 2007; for a discussion, see also Conti - Gaule, 2011), in that a European science believed to be excellent was perceived not to be used properly by firms and entrepreneurs in Europe, not transformed into value added.[1] As a result, the main thrust of efforts to increase the commercial and societal use of academic knowledge consisted in strengthening the so-called third mission of universities, i.e. own commercialization of university-developed inventions through, e.g. technology licensing and academic spin-offs.

The diagnosis of a European paradox was problematic from two aspects. First, empirical data such as bibliometric evidence point to the fact that European science is actually not “excellent” throughout, at least when compared with the US (see, e.g., Albarrán et al., 2010; Dosi - Llerena - Labini, 2006; the various university rankings, including the purely bibliometric Leiden Ranking, make the same point), so that the problem could lie not only with commercialization and transfer, but also with the quality of knowledge production in the first place. Second, a focus on commercialization of academic knowledge neglects the variety of ways universities engage and are linked with businesses and society, including through conferences, joint research or mobility of graduates and researchers (for a survey, see e.g. Perkmann et al., 2013; Veugelers and del Rey, 2014).

This new empirical evidence has made the question of the potential contribution of universities to a new growth path much more complex than simply pushing commercialization of excellent academic science. Can the contribution of universities in Europe to economic dynamism and societal goals be enhanced at all, and if so, how? This paper aims at a unified review of the literature, enabling a more differentiated pursuit of increasing academic contribution to the economy and society and pinpointing further need for research. In so doing, it follows a broader approach than the university entrepreneurship and university industry relations literatures (for

[1] “Compared to North America, the average university in Europe, generates far fewer inventions and patents. This is largely due to a less systematic and professional management of knowledge and intellectual property by European universities.” (European Commission, 2007, p. 3)

surveys, see e.g. Rothaermel - Agung - Jiang, 2007, Perkmann et al., 2013). Reviews of the determinants of university industry relations and university commercialisation have focused on issues such as the technology transfer office productivity, incentive schemes for faculty, IPR policies etc. The main contribution of the paper is to build a comprehensive picture of ways and linkages through which universities can contribute to economic and societal problem-solving and to integrate these linkages into a conceptual model of firm innovation activity. This model is then used for a systematic review of the evidence concerning the impact of university quality on the effectiveness of university linkages with firm innovative activity. So far, there is a dearth of systematic reviews of how research quality affects business science links and prospects for universities to engage with business and society.

Based on the conceptual model, the paper is organized around two core questions:

- Does the quality of academic research and teaching matter for potential innovation and economic benefits? If research quality or scientific productivity matters for the impact of science, then one way forward would of course be strengthening European universities in their two core missions research and teaching (rather than focusing on their "third mission"). *Reframing the question would be to ask whether the EU's lagging behind the US in terms of scientific productivity is a problem for innovation and growth*
- Does research quality, or different research approaches (e.g. incremental/fundamental, basic vs. applied) matter for the most appropriate ways universities engage with firms and society? Does increased research quality of European universities hence ask for a different focus in business-science interactions, or policies to foster such interactions?

Our main results are a new conceptualization of how universities are involved in innovative activity based on micro- or firm-level innovative processes, taking full account of the wide spectrum of university outputs relevant for innovative activity, including the stock of knowledge, flows of new knowledge (research) and trained graduates and researchers. This conceptual model makes clear that paying only attention to science parks, incubators, academic patenting and commercialization is misguided. To maximize the contribution of Europe's universities to a new growth path, one has to get the basics right. We recommend focusing on improving the performance of European universities in their first two missions – research and teaching – rather than trying to improve the third mission – directly contributing to economic development, through, e.g. commercialization - without a sufficient foundation in knowledge creation and distribution. A socio-ecological transition needs the best science it can get. At the same time, we highlight the pitfalls of only using models of role of universities in innovation systems, such as e.g. triple helix, which only look at specific contributions of universities for innovative activities and mostly do not consider the conditions for the effectiveness of proposed ways of interaction, such as the necessary quality of the science base for valorization activities (see also Leten - Landoni - Van Looy, 2014, who make a similar point). In particular, the role of universities in training graduates who then move on to innovative activities within firms is often not stressed enough.

Our main findings of our review of the relevant evidence are that university quality positively affects in particular flows of graduate students and academic commercialization, whereas excellent basic research is potentially negatively related to academic engagement such as collaborative R&D. Research (and teaching) quality is crucial for attracting good students (see also Florida and Cohen, 1999). In terms of policies, this implies that Europe should actively foster the quality of its universities, e.g. through competitive funding and attractive career and organizational structures in open academic labour markets (see Aghion et al., 2008, 2010a; Janger - Nowotny, 2013; Janger - Strauss - Campbell, 2013).

Competitive funding and recruitment policies will lead to increased vertical differentiation of the European university landscape (see, e.g. Daraio et al., 2011) so that top basic research universities can attract top students and researchers, while more applied universities can stimulate firm performance through academic engagement (collaborative R&D, contract research and consulting). Linkages for top research universities work more through mobility of scientists and graduates, as well as through commercialization (licensing technologies or setting up spin-offs), linkages for applied universities work more through academic engagement. In top research universities, new commercialization instruments may be necessary, such as university-internal organizations which bring university discoveries or technologies closer to the market (as practiced, e.g., by the Harvard Accelerator, or at the University of Maryland).

2. The role of universities for innovative activities: a conceptual model

To conceptualise the potential contribution of universities to economic and societal goals, we will look at their role for innovative activities.[2] What do universities produce of relevance for innovative activities by firms and other organizations? How do universities interact with firms and other institutions to become relevant for innovative activities? In the following we will outline a framework for analysing the potential contribution of universities to innovative activity. To capture this potential contribution in full, one has to provide evidence on i) the outputs of universities which can potentially be inputs for innovative activity (what firms or other actors need for innovative activity from universities), ii) the variety of interactions or ways of engagement in which these outputs can actually become inputs for innovative activity and iii) factors which affect the effectiveness of the variety of interactions in facilitating innovative activity. We will describe these elements in turn, adopting a deliberately broad and comprehensive perspective to show from the outset the wide range of ways in which universities can bear on innovation.

2.1 Outputs of universities relevant for innovative activities

Focusing on innovative activity in firms, a first look at the available literature indicates that at an aggregate level outputs of universities, which are relevant for innovations are the following: knowledge, as well as researchers and graduates as carriers of knowledge, and skills how to create more, absorb or use knowledge and successfully applying it (Gibbons - Johnston, 1974; Kline - Rosenberg, 1986; Martin - Irvine, 1981; Salter - Martin, 2001).

Outputs of universities: skills and graduates

The main output of one of universities' core missions, **teaching**, is the dissemination of knowledge and skills through researchers and graduates. Researchers and graduates have been trained in working with knowledge, understanding it, using it, changing and expanding it, they are problem solvers, which is an essential ingredient for innovation and maybe even more important than knowledge itself (see Senker, 1995, for an account of this). As Clark, 1983, p. 12, puts it for the case of university teachers and researchers: "In varying combinations of efforts to discover, conserve, refine, transmit, and apply it, the manipulation of knowledge is what we find in common in the many specific activities of professors and teachers." University-educated people are experts in working with knowledge, which is at the root of innovative activity. In surveys of graduates asking for the most useful outcomes of their higher education training for their current position in industry, respondents most often cite next to the knowledge they gained skills such as individual initiative, ability to overcome complex problems, to communicate effectively, to be part of a team etc. (see e.g. Martin - Irvine, 1981).

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[2] Defined in the Oslo Manual, p. 18, as "Innovation activities include all scientific, technological, organisational, financial and commercial steps which actually lead, or are intended to lead, to the implementation of innovations." OECD - Eurostat, 2005.

These knowledge-related skills can be used in two ways by graduates (and researchers moving into industry): to support innovation by creating new knowledge in firms, or by being able to understand the knowledge created by others (e.g. even through own research), in- and outside of the firm, and to apply it to a given problem (see Cohen - Levinthal, 1989, 1990; Griffith - Redding - Reenen, 2004 on the role of research for both creating new knowledge and absorbing outside knowledge; and the discussion around open innovation): graduates and researchers from higher education, when moving to industry, enhance both research and absorptive capacity of firms. Cohen – Levinthal, 1990, p. 130, cite psychological studies which have established that "experience or performance on one learning task may influence and improve performance on some subsequent learning task". They argue that both learning capabilities, related to the capability to assimilate existing knowledge, and problem-solving capabilities, related to the capacity to create new knowledge, benefit from prior knowledge and learning tasks. In work on the development of computer programming skills, students were most successful when they understood examples of existing computer programmes and developed their own programmes by analogy to these existing ones (see Pirolli - Anderson, 1985, as cited in Cohen – Levinthal, 1990). This clearly shows how participation in higher education develops skills and some of the mechanisms by which they contribute to innovation capacity of firms.

Outputs of universities: knowledge

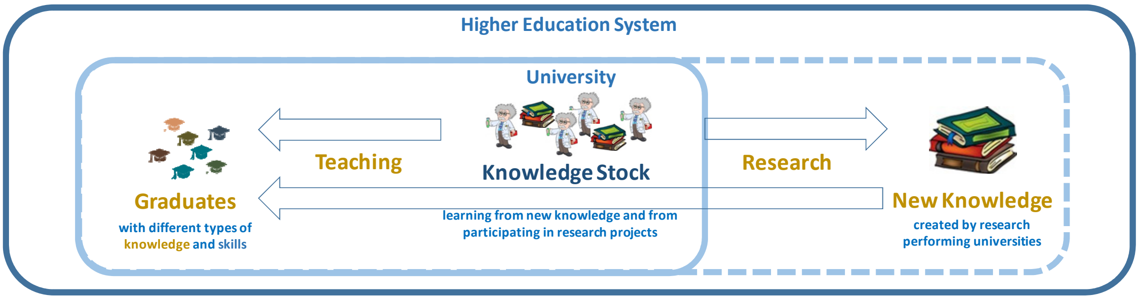
Of course, knowledge itself, not just skills related to dealing with knowledge, coming out of universities, is of great importance for innovative activity. With a view to assess the potential contribution of knowledge originating from universities to innovative activity, we need to differentiate knowledge along two dimensions which are relevant for how university-created knowledge is going to be used in corporate innovative activity. The first is distinguishing between the **stock of knowledge**, i.e. the accumulated result of research in the past; and **flows of new knowledge**, resulting from current research, another core mission of universities. Of course, the former is much bigger and not less relevant for innovative activity, as shown by the often very long time lags between scientific discoveries and their use in commercial application (see Adams, 1990; Kline - Rosenberg, 1986).

Hence the stock of knowledge, the generic knowledge pool (see Salter – Martin, 2001) is usually going to be quantitatively more significant for innovative activity than the flow of new knowledge. However, participating in the creation of new knowledge (e.g. via being involved in research projects) is an important way of learning-by-doing the skills required for carrying out research as well as gaining insights into the most recent developments of current research.

The second distinction concerns tacit vs. codified knowledge, or knowledge which can be accessed in written or formal form vs. "the knowledge of techniques, methods and designs that work in certain ways and with certain consequences, even when one cannot explain exactly why" (Senker, 1995, p. 426, citing Rosenberg, 1982, p. 143). It is important to realise that skills as described above are not tacit knowledge. Johnson - Lorenz - Lundvall, 2002, take this distinction of knowledge further by specifying different types of knowledge that are relevant to the innovation process in firms. They argue that there are four different kinds of knowledge. The first category is “Know-what” and refers primarily to information about facts. “Know-why” refers to knowledge in terms of explanations. A primary example is scientific knowledge that is of primary importance to innovation processes in science-based industries such as electronics or chemistry. “Know- how” denotes the ability to do something, that is skills. Finally, “Know-who” refers to the network aspect of knowledge. With open innovation and the distributed nature of knowledge “know-who” becomes more relevant, also for absorptive capacity. All forms of knowledge are going to be imparted to graduates and researchers, but detailed evidence on which type of knowledge is particularly relevant for the contribution to innovation capacity is missing.

The main outputs of universities relevant for innovation in firms are in summary knowledge, as well as graduates and researchers moving to industry as carriers of knowledge and skills (see figure 1).

Figure 1 **Different types of knowledge and skills as main outputs of universities**



2.2 Ways of interaction and linkages between universities outputs and firm innovative activity

An important determinant of the potential contribution of outputs from universities in all its forms to innovative activities is if and how they become involved with innovative activity by firms or other organisations. We choose a broader term here than “knowledge or technology transfer”, as these terms suggest a linear transferring of university outputs into innovative activity, whereas often innovative activity is based on the interaction of e.g. firm and university researchers, as in joint research e.g.

Ways of interaction through formal or informal business-science links

There is a lot of literature on the categorization of mainly research (and not education) based business-science links, encompassing the traditional “technology transfer” literature, e.g. distinguishing academic relational engagement with industry (such as through collaborative R&D, contract research and consulting) from commercialization (such as patenting and licensing, spin-off creation) (see Perkmann et al., 2013) or distinguishing by the formality or intensity of the link (between informal contacts and complex collaborative research projects) (Hewitt-Dundas, 2012). For instance, knowledge transfer might occur via publications, patenting or licensing of university inventions supported by technology transfer offices, contract research for firms or collaborative research with firms, but also via informal contacts between university researchers and firms. In this setting, university outputs become involved with innovative activity through university researchers and students staying within the realm of the university (possibly with the exception of academic spin-off creation), by contrast with ways of interaction which involve organisational mobility of researchers and graduates. Relational academic engagement is usually much more widespread than academic commercialisation as a way for university outputs to become involved in firm innovative activity (see Perkmann - King - Pavelin, 2011).

Ways of interaction through mobility of graduates and researchers

Although the transfer of knowledge and skills via mobility of graduates and researchers is less explored, an Expert Group commissioned by the European Commission highlights besides indicators related to co-operation and commercialization also those indicators related to people (Expert Group on Knowledge Transfer Indicators, 2011). Knowledge transfer via graduates (but also via student spin-offs) has one big advantage as tacit knowledge cannot be transferred by reading publications, but must be embodied in researchers or graduates. This is one reason why J.R. Oppenheimer states (as cited in Stephan, 2007, p. 71): „The best way to send information is to wrap it up in a person". Empirical evidence furthermore indicates that the hiring of graduates is one of the three preponderant ways of "knowledge transfer" besides informal contacts and publications (see Arundel - van de Paal - Soete, 1995; and Veugelers - Del Rey, 2014, for a survey). In the US, publications, conferences and the mobility of PhD graduates seems to matter more than university prototypes, patents and licences (Cohen - Nelson - Walsh, 2002). The twin function of graduates (and researchers moving to industry) as carriers of the stock of both codified and tacit knowledge and as skilled in problem-solving, in knowing how to create or absorb new knowledge, leads some authors to state that graduates are possibly the most important contribution of universities to innovative activity and thereby economic as well as societal development, even though this is rarely backed up by convincing data (Salter – Martin, 2001, Veugelers – del Rey, 2014).

Florida - Cohen (1999) see universities as economic infrastructures which work through the attraction of talents: universities compete for eminence and reputation through research quality, so that they aim at attracting the best researchers, who in turn attract graduates and undergraduates, who then in turn work at local/regional firms or start-ups, in turn attracting more firms wanting to access the available talent pool. Leten - Landoni - Van Looy (2014) investigate industry differences with respect to the impact of university graduates and knowledge and find that while graduates have a positive impact on technological firm performance in all the sectors examined, university research only has a positive impact in more science-based sectors such as electronics and pharmaceuticals.

Further, indirect support for the importance of graduates comes from looking not at drivers of innovative activity, but at barriers to innovation. This allows in principle for a more focused view: rather than trying to single out one factor among a myriad of different ones driving innovation, firms are asked which barriers to innovation are most impeding their innovative activity. The available evidence shows that in advanced countries, knowledge barriers or more specifically the lack of qualified employees is the barrier most likely to be perceived by firms (see Hölzl -

Janger, 2014). This kind of evidence is often based on the Community Innovation Survey, which does not differentiate by level of education in barriers to innovation and also does not differentiate between different sources of information and knowledge within knowledge barriers to innovation, so that no precise information can be gained about the specific role of higher education.

All in all, it is surprising that so little is known about the importance of graduates as a way to get university outputs involved into innovative activity, compared with the disembodied knowledge outputs of academic research (such as e.g. publications or patents). This is all the more surprising as frequently firms lament the lack of qualified employees, as well as of science and technology graduates, but they seldom complain about a lack of e.g. of patents (see, e.g., Milne, 2013). At the same time, public policy in some European countries sometimes seems to criticise universities as ivory towers for their lack of cooperating with firms, while universities call for more funding for their core missions research and teaching, which would lead inter alia to a higher stream of graduates potentially working in industry. Clearly, there needs to be more evidence as to which way of interaction matters most to firms and other organisations, able to guide public policies and universities in terms of resource allocation and priority setting as regards the ways of interaction between universities and firms and society with a view to fostering innovative activity.

In summary, individuals (e.g. graduates, participants of advanced training, etc.) are seen as one of the main carriers disseminating knowledge and skills from universities to firms (and the rest of the society), helping both to access the stock of knowledge and to create new knowledge in firms, but there is little systematic evidence to back this up. On the contrary, public policy often seems to be focused on fostering commercialisation of academic research results, or on increasing cooperation intensity between universities and firms. Table 1 shows the various linkages according to different criteria.

Table 1 **Various forms of university-industry linkages and interactions**

	Linkages by intensity of relationship		
Active forms			
Academic engagement	Collaborative R&D	Contract Research	Consulting
Academic commercialisation		Intellectual Property Creation and licensing	Academic entrepreneurship (spin-off creation)
Linkages through people		Mobility of researchers	Mobility of graduates
Passive forms			
			Absorption of academic research and knowledge through publications

Source: Own compilation based on Perkmann et al., 2013, and Hewitt-Dundas, 2012

2.3 Factors shaping the effectiveness of different ways of interaction in contributing to innovative activity

After discussing higher education system outputs and how they interact with the innovation process of firms, it remains open what determines the effectiveness of the different ways of interaction in contributing to innovative activity. In other words, e.g. what skills and knowledge should be taught at universities to increase the contribution of universities to innovative activity in the wider economy and does the answer to this question depend on other external factors such as specifics of a given country, technology field or industrial sector? What conditions the effectiveness of interaction ways such as joint research, classic technology licensing, etc.? The literature suggests various factors which affect the potential contribution of universities to innovation activity.

Examples are e.g.

- How university quality – or the position of the university in a hierarchy of quality based on several indicators (vertical diversity, see Daraio et al., 2011) – or research/teaching quality impacts on choice of interaction mode, use of research results and the immigration of talented young scientists (Hunt - Gauthier-Loiselle, 2008; Mansfield, 1995; Perkmann - King - Pavelin, 2011). E.g., evidence shows that graduate mobility, in particular of PhDs, is partly driven by university prestige and quality (Van Bouwel - Veugelers, 2012, 2013), and firm R&D centre location is sensitive to university research quality (Abramovsky - Harrison - Simpson, 2007) while the presence of star scientists fosters start up creation (Zucker - Darby - Brewer, 1998). This will be examined in detail below (chapter 2.2)
- The importance of geographic proximity for knowledge and graduate, researcher flows (e.g. Abramovsky - Simpson, 2011); how higher education institutions are embedded into their regional context and economy and which factors influence this (e.g. see Lester - Sotarauta, 2007).
- How industrial specialization impacts on the demand for universities' outputs; e.g. specialization in science- vs. development-based industries, high-tech vs. medium-tech industries affects the composition of demand by firms for universities' outputs (Czarnitzki - Thorwarth, 2012; Gilsing et al., 2011; Robertson - Smith - von Tunzelmann, 2009)
- How industry lifecycles impacts on the demand for universities' outputs: when there is a new industry emerging (possibly through academic breakthroughs) which requires new skills, what is the role of universities?
- Determinants of effectiveness of technology transfer offices, science parks and others (see Veugelers and del Rey, 2014, for a recent survey) How IP regimes affect incentives to commercialise academic research (e.g., see Mowery et al., 2004, Rothaermel - Agung - Jiang, 2007)
- How horizontal differentiation of a university (in terms of subject mix, e.g. a focus on vocational vs. general training; type of research activity and involvement into third mission activities) impacts on innovative activity, e.g. through incremental vs. radical innovation and hence growth (Hall - Soskice, 2001; Krueger - Kumar, 2004a, 2004b; Daraio et al., 2011))

- There are few studies investigating the way teaching and other features of higher education such as internships are affecting the innovative potential of graduates, including entrepreneurial attitudes.

The most important conclusion to be drawn from these studies is that quantity, quality and types of universities' outputs are not always contributing in the same way to innovative activity. Their effectiveness depends on factors which higher education institutions can directly influence (such as teaching ways, teaching and research quality) and on factors where universities have only indirect, medium-term impact, such as the level of development (distance to the technological frontier) and the economic and industrial structure (whether, e.g. a large share of science-based industries demands a lot of researchers, graduates and knowledge from the higher education system), as well as extent of regional agglomeration.

Moreover, this effectiveness is not static, but changes over time: a stream of knowledge, graduates and researchers moving from universities to industry creates the opportunities and the necessary workforce for the expansion of more knowledge-intensive sectors of the economy. This is an issue of circularity, with universities feeding the growth of knowledge-intensive sectors, which in turn demand more outputs from universities. Furthermore, the composition of the most important skills might also vary over time. For instance, if firms in a technologically catching-up country switch from an imitation to an innovation strategy creative research skills gain importance whereas imitative skills lose. This most often happens if a country approaches the world technology frontier (e.g. Aghion et al., 2005; Hölzl - Janger, 2014; Vandenbussche - Aghion - Meghir, 2006). Anyhow, the broad range of existing technology fields, the various types of innovation modes across sectors (Peneder, 2010), the different stages in the innovation process (within a firm), the heterogeneity across stages of development across countries and regions make it difficult to summarise which skills and knowledge are the most important in general.

The table below summarises the framework for capturing the potential contribution of universities to innovative activity, or the elements discussed so far. This again shows that the question of academic patenting or commercialisation of academic research results is only among many ways how universities can become relevant for innovative activity, the effectiveness of which depends in turn on many different factors.

Table 2 **A framework for capturing the role of universities for innovative activity**

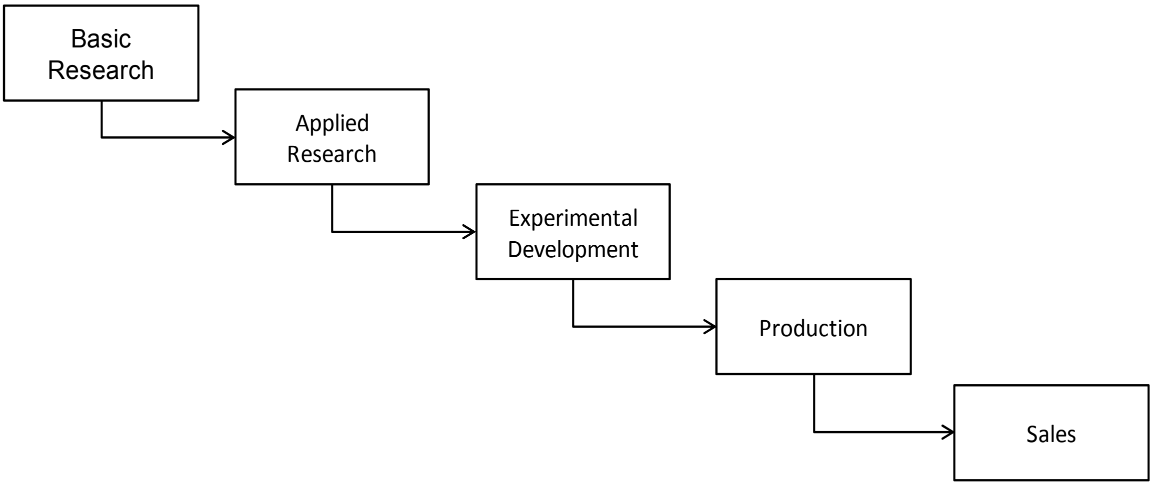
Outputs of Universities	**Ways of interaction:** how outputs of HES become inputs for innovative activity	**Effectiveness** of interaction – **crucial factors**
• **Knowledge** ○ Stock of knowledge vs. new knowledge (research) ○ Tacit vs. codified knowledge ○ Know-who, know-what, know-why, know-how • **Graduates and Researchers** ○ Carriers of skills and knowledge	• **New knowledge** ○ Patenting and licensing ○ Spin-offs ○ Contract research ○ Collaborative research • **Stock of knowledge** ○ Graduates and researchers moving into industry ○ Publications ○ Informal contacts	○ Research & teaching quality, way & contents of teaching, ... ○ Distance to the frontier ○ Industrial specialisation ○ Geographic proximity ○ Quality of Technology transfer offices ○ University IP policies ○ Science Parks

2.4 Modelling innovative activity with a special emphasis on the role of universities

So far, we have only discussed individual elements of how universities become relevant for innovative activity. To strengthen our argument, we embed the interactions discussed in innovation process models. In our review of models we will be heeding the findings from Forrest, 1991 and Senker, 1995 that no single model can show all processes of technological innovation, and that it may be more productive to be aware of the variety of typologies of innovation. In our case, we need a model that shows the inputs of higher education into the innovation process of firms, even if this model may neglect other determinants of innovation, as long as those determinants don't interfere with the potential contribution of universities to innovation. A proper innovation model for our purpose must be able to trace the contribution of universities to innovation at firm level in the form of both knowledge and graduates (incl. further education). It also needs to consider the stock of knowledge incl. the results of research (new knowledge) and its role for innovative activity, as well as factors which impact on the effectiveness of the contribution of universities to innovative activity.

An overview of models shows that among the many interactions possible, many only treat research explicitly, disregarding the people who do the research as well as non-research sources of innovation. Many models are silent on the role of graduates (and the skills they need) and the activity of researchers is simply assumed without showing it explicitly. A classic example is the linear model (a "stage model" of innovation, i.e. innovation proceeds in sequential stages), shown in Figure 2 (see Bush, 1945). It does not feature tapping into the stock of knowledge and has no role for firms' own innovative ideas, where graduates could play a distinctive role. In the linear model, new knowledge is created exclusively from basic research (new knowledge) which finds its way through applied research and experimental development into the production and sales stages of firms' activities.

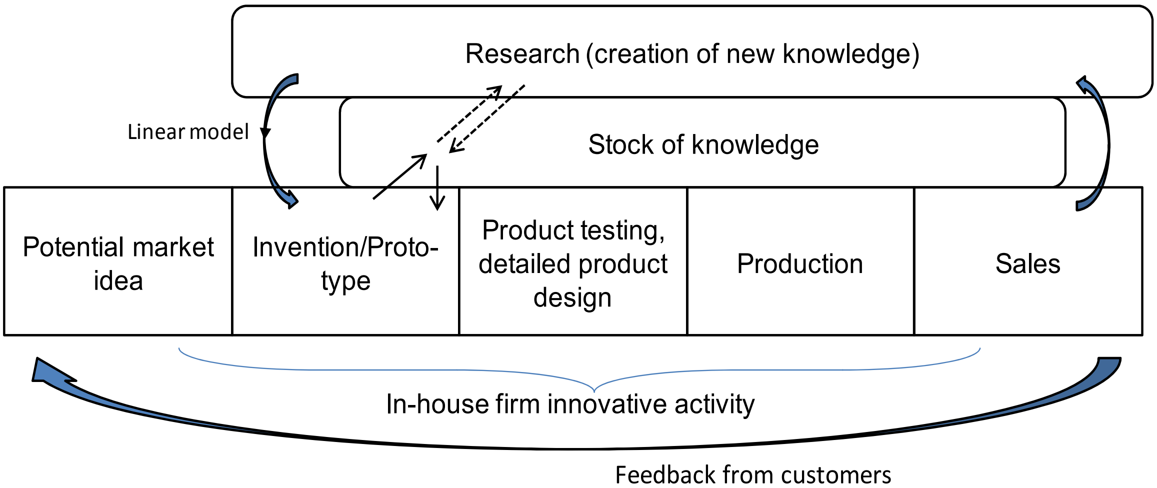
Figure 2 **The linear model of innovation**



Source: Own illustration

Although this model implies a very large role for universities in innovation as a main provider of basic research and there are many examples of innovations which have been developed that way (e.g., the transistor), it does not fully account for universities' outputs in terms of skills and embodied knowledge of graduates. It ignores important parts of the reality of firm innovative activities, which often initiate innovations based on their own ideas, turning only later to outside R&D for problem-solving in the midst of the innovation process, and policy-wise leads to an emphasis on technology transfer push model and policies, such as fostering academic patenting and licensing. A more general model which encompasses the linear model and is closer to reality, in that it can account for both the activity of graduates in innovation and for the use of knowledge from universities, while allowing firms to initiate innovation independently from basic research, is an adapted chain link model (originally described by Kline - Rosenberg, 1986; Kline, 1985).

Figure 3 **The innovation process according to the chain link model (simplified)**



Source: Adapted from Kline – Rosenberg, 1986.

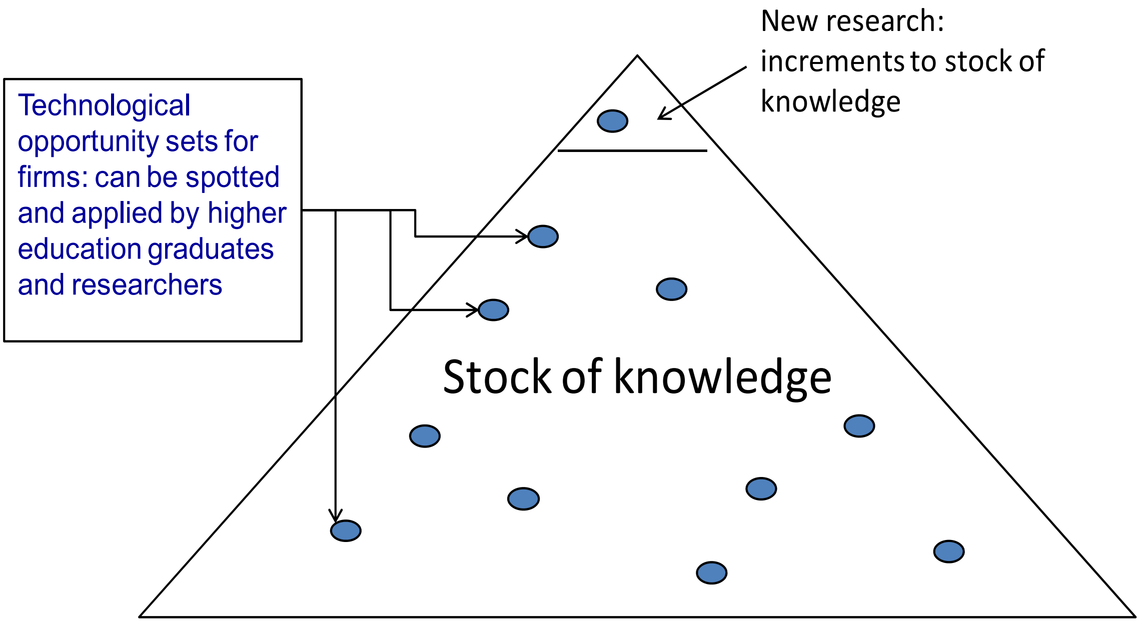
The model sets out with the recognition of a market need by the firm, or an idea. There is an invention made to cater for that need, which goes then through further stages such as product testing, design, actual production and sales. At each stage, when employees active in the innovative activity can't solve a problem based on their skills and their knowledge, they stop and check what existing knowledge is out there (indicated by the arrow from invention to stock of knowledge; in each stage there should be such arrows, but for the sake of simplicity they have been dropped) which could help them. Only when nothing in the stock of knowledge can help solving the problem, research is undertaken, either own research or research from and with outside sources such as universities.

The special linear case is when research leads to a new product idea (the arrow from research to invention). This model is interesting because it allows in principle both for the role of knowledge and graduates, the stock of knowledge and new research; and for a large range of transfer mechanisms, based on both the transfer of knowledge and of graduates. Because it separates in-house firm innovative activity from other (external) knowledge inputs and research, it is also able to account for different ways of the contribution of higher education to innovation, such as e.g. industry specialization – where science-based industries will more often tap into new knowledge, whereas low-tech industries will use existing knowledge to upgrade their technological base.

As Aghion et al., 2010b; Aghion - Dewatripont - Stein, 2008, point out, the advantages of the private sector lie in its focusing capability to concentrate on getting technologies ready for market introduction driven by profit considerations, whereas academic research is good at the early stages of a new technology, attempting lots of different research avenues driven by the curiosity of academic researchers. As a result, linkages which involve the creation of new academic knowledge are more likely at the beginning of the innovation process, whereas problems which surface in later stages of product or technology development are likely to be dealt with internally or through consulting the stock of existing (academic) knowledge.

Another interesting view on how higher education contributes to innovation comes from Klevorick et al., 1995, who conceptualise basic research as a source of technological opportunities for firms, basic research feeds a pool of technological opportunities in which firms can tap to produce innovations. In this model graduates and researchers from universities could be seen as exactly the ones that spot technological opportunities which can be turned into new products (see Figure 4).

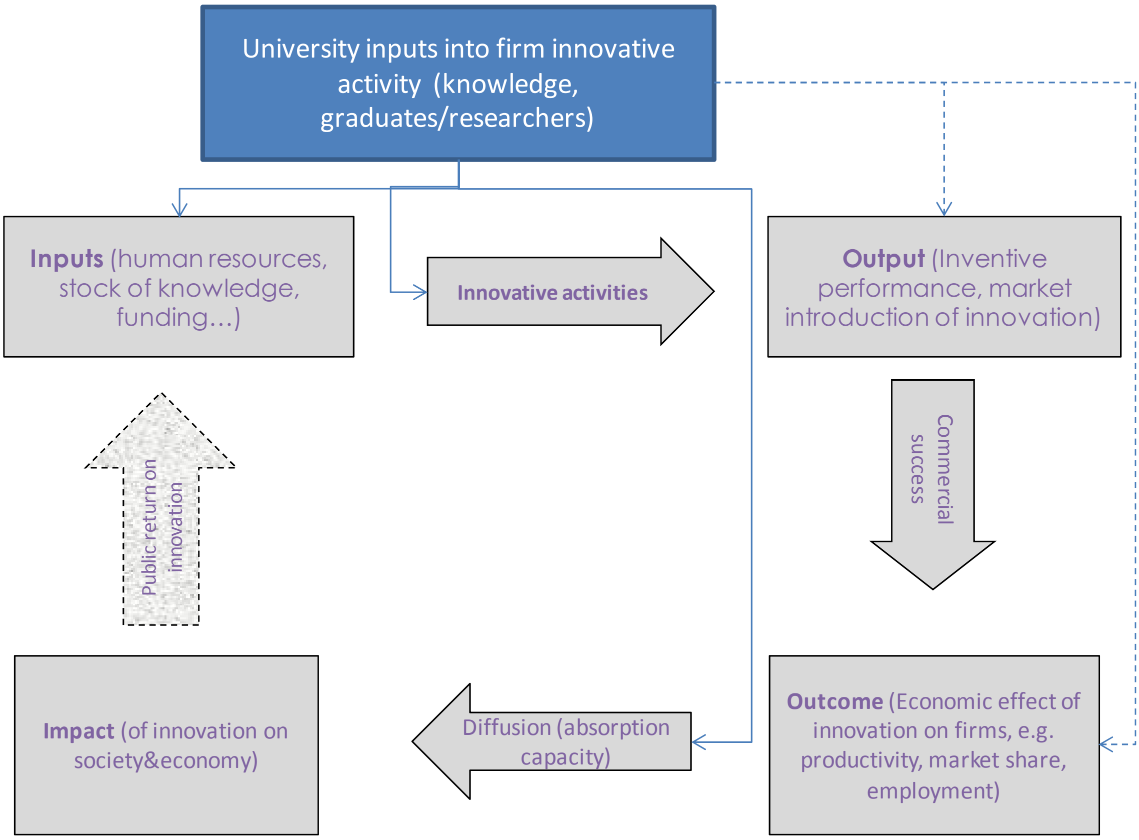
Figure 4 **Universities as a source of technological opportunity sets for firms and as a source of trained workers who can identify these opportunity sets and use them for the firm**



Source: Adapted from Klevorick et al., 1995.

A more abstract model of the innovation process can be found in innovation production function models or logic chain models used in the evaluation literature. A firm needs inputs for its innovation process, e.g. funding, human resources (trained researchers, e.g.) or lab equipment. These inputs are used in firm innovative activity or in an innovation process, potentially leading first to codified technology (patents) or publications as an intermediate output and then to market introduction of an innovation, such as a new product. Outcomes for the firm which has introduced the innovation depend on the commercial success of the output, taking the form of productivity, market share, profit or employment gains. The economy-wide benefits of the innovation – the "impact" – depend in turn on proper diffusion of the innovation to customers, suppliers and competitors of the firm. It can easily be seen that universities' outputs (knowledge and graduates) are crucial innovation inputs for firms and hence play a large role in innovative activity; but university outputs are also crucial for successful diffusion, as the skills of graduates determine absorption capacities of firms (see section 2.1).

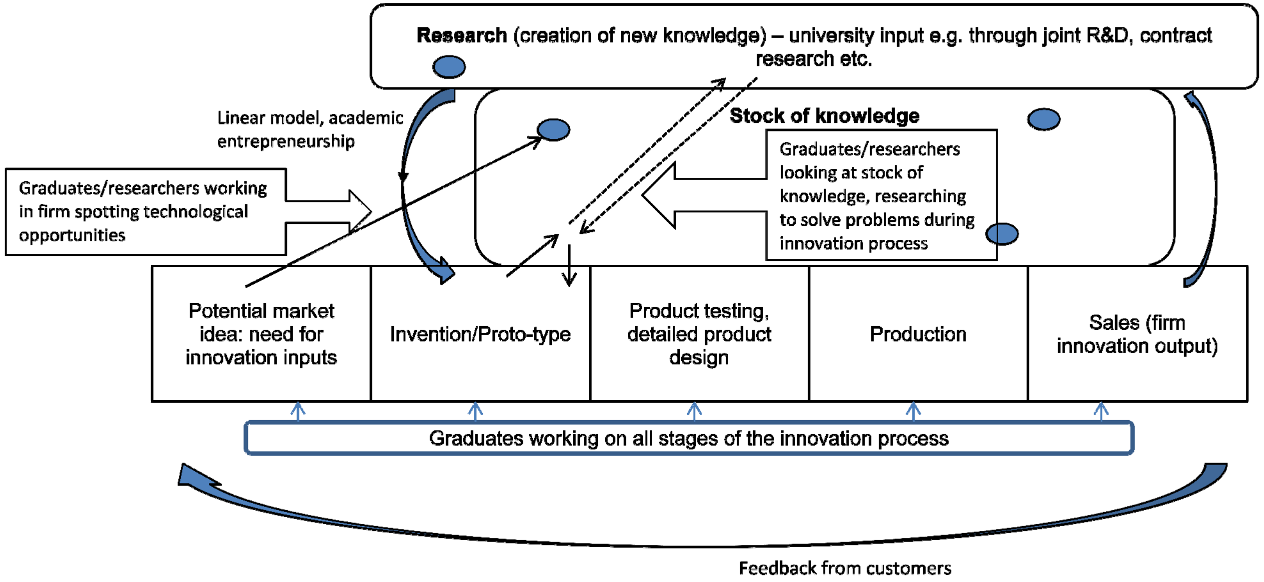
Figure 5 **Universities as a source of inputs for firm innovative activities**



Source: Own illustration

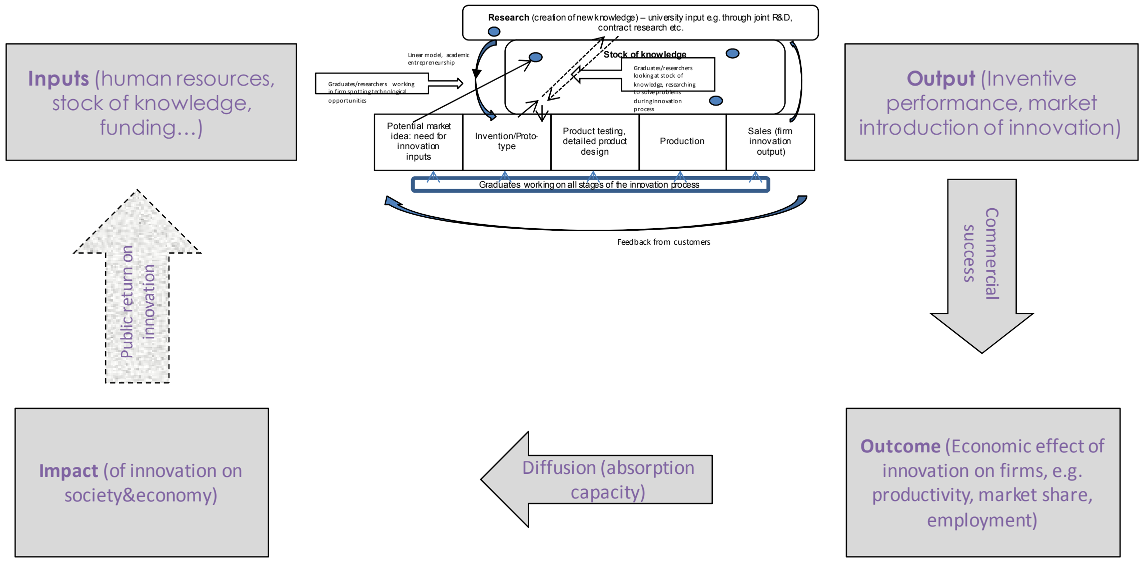
An attempt at linking these different graphic conceptualisations can be seen in Figure 5. The core innovative activity mirrors the chain link model, while inputs and outputs as well as the role of technological opportunity sets are shown.

Figure 6 **A conceptual model for the role of universities in innovative activity**



The figure above can be seen as detailing the arrow “innovative activities” in the logic chain model (Figure 6). Replacing this arrow with the actual model situates the conceptual model:

Figure 7 **Conceptual model for the role of universities in innovative activity within the logic chain model**



Other models which conceptualise the role of universities for innovative activity are the triple helix model (see, e.g. Etzkowitz - Leydesdorff, 2000) and the national innovation system model (see, e.g. Lundvall, 2010; Mowery - Sampat, 2005). While both are important in that they stress the contribution of universities to innovation, this contribution is not outlined at the level of firm innovation processes, making them less useful as a guide for fully identifying the contribution of universities to innovation at the firm level. In addition, the triple helix focuses on the 3rd mission of universities in terms of technology transfer, on research, which could turn out to be only a small fraction of the total contribution of universities to innovation (see above) and is furthermore more related to research than to universities themselves.

What is the empirical evidence so far for the role of the university for innovative activity, for the impact of universities’ outputs on the process outlined above? While the evidence concerning knowledge, and in particular research (new knowledge), is abundant, studies investigating the role of university-trained graduates and researchers are surprisingly rare.

Concerning the evidence for knowledge, recent brief surveys of the literature can be found, e.g., in Fleming - Sorenson, 2004; Van Looy et al., 2011; Veugelers et al., 2012; Veugelers - Del Rey, 2014. There is evidence for the positive effect of university inputs on both firm innovation outputs (e.g. technological performance, introduction of innovation, filing of patents) and outcomes (e.g. productivity growth at the firm and country level). As regards firm outputs, for example, Jaffe, 1989, finds a positive relationship between university R&D expenditures and local firm patenting rates; Cohen - Nelson - Walsh, 2002 find strong survey-based evidence that university-based public research matters for industrial R&D. Many studies find that collaboration with university researchers external to the firm increases firm R&D productivity (e.g., Zucker - Darby - Armstrong, 2002.

As regards firm outcomes or society-wide impacts, Adams, 1990 finds that cumulative research output (stocks of knowledge), in the form of published papers, boosts growth rates. Mansfield, 1991 finds effects on both firm innovation outputs (in terms of, e.g. speed of innovation implementation) and outcomes (in terms of sales generated via innovations). Guellec - Van Pottelsberghe de la Potterie, 2003 show that the long term social return to public R&D, and especially to its part performed in the higher education sector, is higher than the one on business funded R&D.

While the importance of graduates seems obvious, there is relatively little research investigating more thoroughly their impact on firm innovation outputs and outcomes. Leten - Landoni - Van Looy, 2014 find that firms' innovation output as measured by patents benefits from nearby university graduates in all industries, whereas university research (knowledge transfer) matters only to selected science-based industries (electronics and pharmaceuticals). Rothaermel - Ku, 2008 compare innovation performance of medical clusters (again measured by patents) and find that research university graduates influence innovation performance positively. Further away from firm-level innovative processes are Furman - Hayes, 2004 and Furman - Porter - Stern, 2002, who find positive effects of investments in science and education on the innovative performance of (national) innovation systems. At an even higher level of aggregation, the human capital and growth literature finds positive effects of higher education on growth in countries close to the technological frontier. One presumed channel is the role of graduates in innovation (see, e.g. Vandenbussche - Aghion - Meghir, 2006, Aghion et al., 2005).

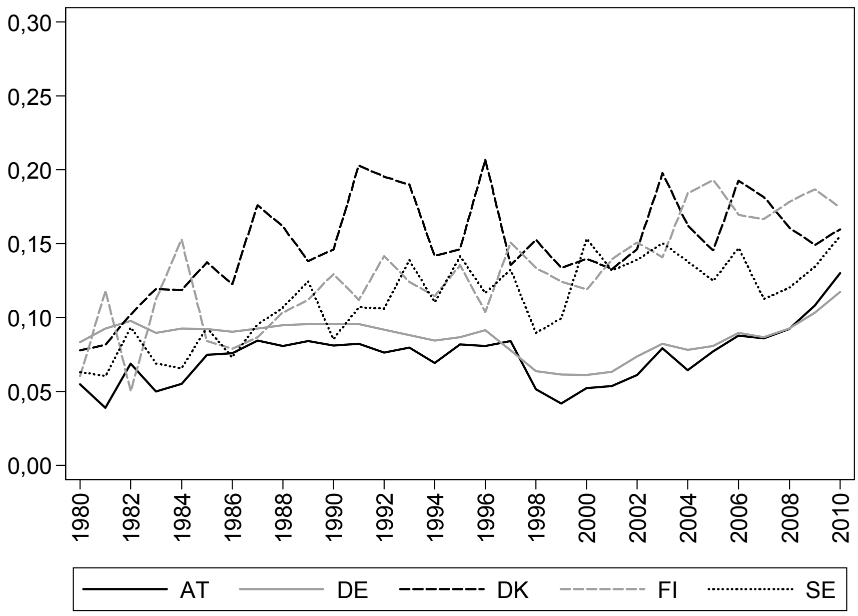
Of course, one should not just look at the effects of university involvement on firm innovative activity, but also at the effects of the other way round, the effect of university involvement on university knowledge creation and teaching graduates. For collaborative R&D, there seems to be a U-shaped relationship, with some involvement (also depending on disciplines) at least not detrimental to research performance, but too much clearly showing negative effects (Banal-Estañol - Jofre-Bonet - Lawson, 2015).

2.5 Increasing role of universities for innovative activity

Both elements of universities - research and higher education - are of high importance for the innovation system of a country or region and its capacity to provide new technologies and support innovation in general. The dimension of universities' role in innovative activities depends on changing supply and demand conditions for university outputs.

Two demand-side trends indicate that the importance of universities for innovation activities of EU countries is likely to increase even more in the near future. Firstly, innovative activities increasingly draw on academic research as a necessary input (e.g., Narin - Hamilton - Olivastro, 1997; Veugelers - Del Rey, 2014). The reasons for this are manifold, but are not least related to the increasing complexity of innovation: it becomes ever more difficult to improve upon the existing products and technologies, leading to a "burden of knowledge" (Jones, 2009). Firms using scientific research findings usually gain a better understanding of technological landscapes in which they search for new solutions to problems, increasing their R&D productivity. In turn, the return on science is influenced by the difficulty of the problem addressed (Fleming and Sorenson, 2004). This is also a driver of open innovation strategies which through tapping into public science pools allow for more rapid access to problem-solving knowledge (Chesbrough - Vanhaverbeke - West, 2006, Klevorick et al., 1995). Figure 8 shows that the share of academic publications in the citations of corporate patents has more than doubled in 30 years, which confirms that academic research becomes ever more important to innovative activity by firms. It would be interesting to trace the evolution of university-trained workforce in firms' R&D and innovation departments.

Figure 8 **Share of academic publications in total citations of corporate patents, 1980-2010**

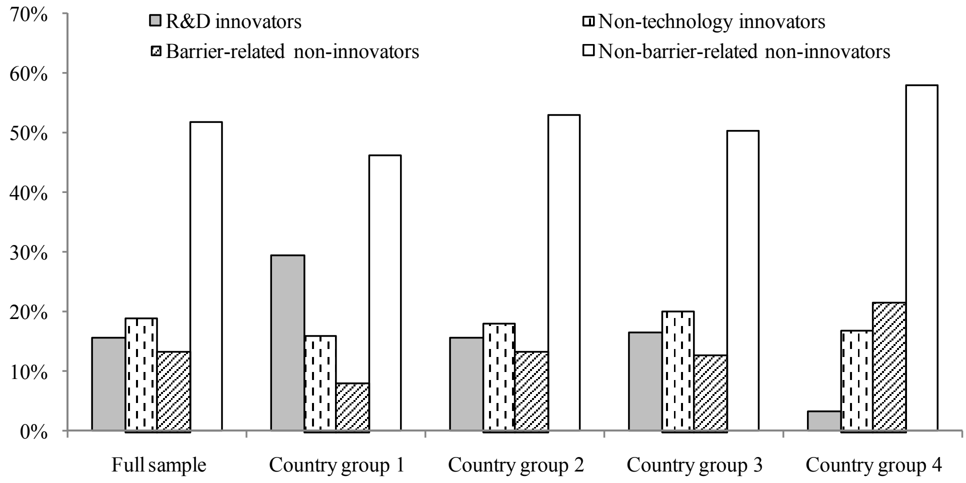


Source: OECD, REGPAT database, June 2012 und OECD, Citation database, June 2012.

Secondly, theoretical and empirical studies have shown that as countries approach the technological frontier – or the highest level of productivity which currently exists - , firms need to switch from imitation- or investment-based strategies to innovation-based strategies, where the creation of own knowledge is of paramount importance in establishing competitive advantage (Acemoglu - Aghion - Zilibotti, 2006; Aghion - Howitt, 2006; Vandenbussche - Aghion - Meghir, 2006).

The figure below shows the shares of different firm innovation modes among countries in the EU, grouped by their distance to the frontier. Group 1 corresponds to advanced, knowledge intensive countries such as Germany; group 2 to catching up former transition countries such as the Czech Republic; group 3 to Southern European countries with structural problems; group 4 to lagging former transition countries such as Romania. It is obvious from the figure that firms in different countries and at different stages of technological development are likely to have different skill and knowledge needs for innovative activity – more firms are engaged in innovative activity in advanced countries, but there is also more formal R&D based innovative activity relying more on advanced science and engineering skills, possibly developed though exposure to basic academic research, whereas more investment-based learning strategies (non-R&D based innovation) are more frequent in catching up countries which may rely more on technical skills for incremental adaptation of technologies developed elsewhere. Moreover, in advanced countries, skill barriers are the barriers most likely to be perceived by firms engaged in innovative activity, whereas in catching-up countries, financial barriers (i.e., raising external finance for innovation projects) are as or even more important than skill barriers.

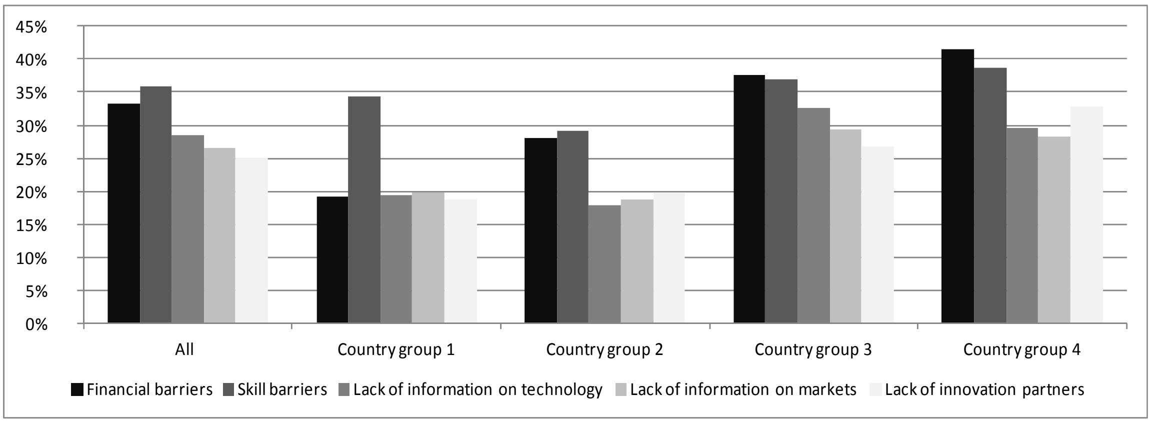
Figure 9 **Distribution of innovator types across country groups**



Source: Hölzl and Janger, 2014. CIS 4 and CIS 2006 data accessed at Eurostat Safe Centre. Values are averages over CIS 4 and CIS 2006 aggregates. Country Group 1: High direct technology intensity:: Belgium, Germany, Denmark, Netherland, Finland, France, Sweden, United Kingdom; Country Group 2: High indirect technology intensity: Czech Republic, Slovenia, Slovak Republic, Hungary; Country Group 3: Low technology intensity with higher GDP per capita: Spain, Portugal, Italy, Greece. Country Group 4: Low technology intensity with lower GDP per capita: Poland, Lithuania, Romania, Bulgaria, Latvia.

Furthermore, European evidence, confirms that knowledge creation as an innovative strategy dominates in advanced European countries and that in such countries, knowledge barriers and more specifically the lack of qualified employees, rather than the cost of innovation, are the main barrier to innovative activity (Hölzl - Janger, 2014; see figure below).

Figure 10 **Lack of skilled employees as a barrier to innovation by distance to the frontier**



Source: Hölzl and Janger, 2014.

A further trend which leads to increased importance of universities for innovative activity is skill biased technical change, meaning that technological progress favours more highly skilled employees. Innovative activity depends crucially on the supply of highly educated workers and, in turn, innovation processes increase the demand for highly educated workers. Technological change and innovation affect the structure of labour demand (see e.g. Acemoglu, 1998).

At the supply-side, the university and innovation policy focus on academic entrepreneurship, commercialisation, cooperative R&D and knowledge transfer in general, driven inter alia by triple helix and national innovation system concepts (see above) means that universities are now much more actively pursuing commercialisation and engagement in informal and formal links to industry (see also van Looy et al. 2011, Geuna - Muscio, 2009). As a consequence, a "second academic revolution" is associated with a more preponderant third mission of universities concerned with directly supporting economic development through academic entrepreneurship, e.g. Etzkowitz et al., 2000; the view is that universities should not just create and teach new ideas, but also help in commercialising them or in developing them into marketable technologies. Graduation rates are also increasing everywhere, as people strive for better qualifications (see also introduction).

As a result, well working higher education systems can increasingly be seen as the backbone of knowledge-based societies, playing essential roles not only for the competitiveness of firms, but also for facilitating social and regional innovation capacity. At the same time, detailed information and indicators which provide an understanding of how universities contribute to innovation activities, in particular for graduates, which could inform policies directed at improving the potential contribution of universities to innovation capacity, is often lacking. As outlined, a lot of the literature has focused on academic patenting and licensing, as well as on other forms of interaction mainly involving research (rather than the stock of knowledge available), such as publications, joint research, spin-offs etc. It is noteworthy that the EU-initiative Innovation Union (European Commission, 2010) focuses on the transfer of research results through technology transfer offices, rather than on graduate mobility as a strong vehicle for making universities a valuable input for innovative activity. Measuring the contribution of universities for innovative activity was up to now mainly analysed through the perspective of research and development (R&D), largely disregarding the role of graduates and also the inputs of non-science and engineering study fields, such as social and management sciences, arts and humanities can bring to innovative activity.

Focusing on transferring the knowledge produced in universities to firms and societal actors through disseminating research results or traditional business-science links (e.g., collaborative research as in the Framework Programmes of the EU) was possibly also driven by the perception of a "European Paradox", i.e. the conjecture that EU countries play a leading global role in terms of top-level scientific output, but lag behind in the ability of converting this strength into wealth-generating innovations (see Conti and Gaule, 2001, and Dosi et al., 2006). For the improvement of a firm's capacity to innovate, it matters to understand not only the relevance of academic research, but also other significant factors such as human capital, skills development, "intrapreneurship", organizational capacity and entrepreneurship, factors that are rather produced by the teaching side of universities, that should be recognised by education and innovation policies and measures as well as indicators.

From this view of the role of universities role in innovative activity, how can we move forward to foster a new growth path? What is the evidence on improving ways of interaction? What is often overlooked is the role of university quality for the role university outputs can play in innovative activity. When teaching and research quality are important determinants of the contribution of universities to innovation capacity, then an overly narrow focus on commercialisation without looking at the conditions for its effectiveness would be misplaced. In the next section, we are hence going to examine the literature on how quality or scientific productivity affects universities' impact on innovation.

3. Do research and/or teaching quality matter for the impact of universities' contribution to innovative activity? A review of the literature

There is widespread evidence that research and teaching quality matter for the impact of universities on innovation and economic performance. E.g.,

- R&D intensive firms locate close to high quality universities (Abramovsky et al., 2007, Belderbos et al., 2009)
- Star scientists boost firm entry and start-up creation (Zucker and Darby, 2007, p. 4) „geographic distribution of new science-based industry can be mostly derived from geographic distribution of human capital embodying the breakthrough discovery upon which it is based"; also Di Gregorio and Shane, 2003, find correlation of scientific productivity with start-up creation
- Technology transfer activity is more successful in high productivity-universities (Conti and Gaule, 2011)
- Top research universities attract top (foreign) (PhD)-students, which e.g. in the US contribute disproportionately to innovation performance (Van Bouwel and Veugelers, 2012, 2013); Hunt - Gauthier-Loiselle, 2008)

In a systematic review of how academic engagement (relational academia industry links such as joint R&D) differs from academic commercialisation (university spin-offs, or licensing of university patents), Perkmann et al., 2013, find a clear picture that at the individual level, scientific productivity is positively associated with both forms of research-based university contributions to innovative activity, engagement and commercialisation. However, at the organisational level (department or university level), academic engagement is negatively associated with research quality in some studies and uncorrelated in other studies, whereas commercialization is also positively related to research quality at the organizational level. Perkmann et al. (2013) hypothesise that thay may be due to highly motivated individuals not necessarily affiliated to higher quality research institutions who see academic engagement as a resource producing device at lower ranked institutions, where fewer resources are available. Top-publishing university researchers however also feature high levels of patenting and academic entrepreneurship. Prima facie evidence from bibliometric university rankings confirm this finding. Figure 11 shows first universities ranked according to their share of journal articles which are among the top 10% cited worldwide, i.e. ranked according to research quality. The picture is familiar, with most universities among the top 25 from the US. The picture below shows universities ranked according to the share of articles co-authored with industry researchers. Here, the ranking is totally different, with only one US university among the top 25 and generally the top US universities according to research quality not being the top collaboration universities.

Figure 11 **University ranking according to research quality and according to collaboration intensity with industry, 2015**

Rank	University	Country	P	PP(top 10%)	Stability interval
1	MIT		10040	24.8%	
2	Harvard Univ		31137	22.1%	
3	Stanford Univ		14102	21.9%	
4	Univ Calif - Berkeley		11804	21.8%	
5	Princeton Univ		5175	21.5%	
6	Caltech		5097	21.4%	
7	Univ Calif - Santa Barbara		4258	20.3%	
8	Univ Calif - San Francisco		10199	19.8%	
9	Rice Univ		2433	19.1%	
10	Weizmann Inst Sci		2414	19.0%	
11	London Sch Hyg & Trop Med		1724	19.0%	
12	Univ Calif - Santa Cruz		1971	18.6%	
13	Yale Univ		10331	18.5%	
14	Univ Texas - Southwestern Med Ctr		4235	18.4%	
15	Ecole Polytech Fed Lausanne		5015	18.2%	
16	Univ Calif - San Diego		11707	18.1%	
17	Univ Oxford		12935	17.8%	
18	Univ Chicago		7043	17.6%	
19	Columbia Univ		11807	17.5%	
20	Univ Calif - Los Angeles		14002	17.4%	
21	Northwestern Univ		9798	17.3%	
22	Univ Colorado - Boulder		5216	17.3%	
23	Univ Cambridge		12170	17.3%	
24	Univ Penn		12649	17.2%	
25	ETH Zurich		8196	17.1%	

Rank	University	Country	P	PP(industry)	Stability interval
1	Eindhoven Univ Technol		5774	14.5%	
2	Osaka Prefect Univ		2395	13.0%	
3	Tokyo Univ Agr & Technol		3053	12.8%	
4	Delft Univ Technol		8195	12.7%	
5	Chalmers Univ Technol		4718	12.1%	
6	Tech Univ Denmark		8575	12.0%	
7	Pohang Univ Sci & Technol		5430	12.0%	
8	Japan Adv Inst Sci & Technol		8767	11.9%	
9	Rensselaer Polytech Inst		2939	11.5%	
10	KTH Royal Inst Technol		7707	11.3%	
11	Waseda Univ		4390	11.1%	
12	Semmelweis Univ Budapest		2820	11.1%	
13	Tokyo Inst Technol		9011	10.8%	
14	Aalto Univ		4935	10.4%	
15	Cranfield Univ		2035	10.3%	
16	Kinki Univ		2910	10.3%	
17	Shinsu Univ		3138	10.3%	
18	Korea Adv Inst Sci & Technol		8535	10.1%	
19	Tokyo Univ Sci		3179	10.1%	
20	Tohoku Univ		17131	9.9%	
21	Aalborg Univ		2923	9.9%	
22	Graz Univ Technol		2317	9.8%	
23	Grenoble INP		3016	9.8%	
24	Kanazawa Univ		3908	9.7%	
25	Budapest Univ Technol & Econ		2088	9.6%	

Source: CWTS Leiden Ranking 2015, http://www.leidenranking.com/ranking/2015.

For graduates, such a systematic review is lacking. We add to this by applying an input-output framework to the literature, enabling us to pinpoint where evidence is weaker and stronger. Often, the literature does not differentiate whether university quality affects university outputs themselves (relevant for innovative activity) – i.e. firm innovation inputs – or firm innovation outputs and outcomes. To get a clear picture of the role university quality plays for firm innovative activity, we need evidence not just on firm innovation inputs, but also on how university outputs affect firm outputs and outcomes. Our literature table will use the following structure:

University/individual researcher quality can affect the following dimensions relevant for innovative activity:

- University outputs relevant for innovation (non-firm innovation inputs)
  - Academic commercialisation and entrepreneurship
    - patenting by faculty (e.g. higher research quality, more patents)
    - licensing, licensing income
    - Number of university start-ups the alternative to licensing technology to established firm)
  - Graduates: attracting top students
- Effect of university quality on firm innovation process
  - Academic engagement (university-industry relations)
    - Involvement in collaborative R&D, contract research, consulting (e.g. higher research quality, more engagement?)
  - Location of firm R&D centres close to universities (e.g., R&D centre location influenced by university quality?)
- Effect of university quality on firm innovation output, technological performance (mediated through university outputs/innovation inputs and process factors)
  - Intermediate outputs: Quality and quantity of inventions (e.g., measured through patents); e.g. are patents which are outcome of industry-(high research-quality-)university collaboration, or which cite high quality academic research of greater novelty and value?
  - Quality and quantity of innovations, e.g. as in novelty, radicality, e.g. role of graduates from high quality research universities for technological performance
  - Increasing R&D productivity, e.g. through more efficient/effective search
- Effect of university quality on firm innovation outcomes
  - Commercial success of innovation, sales share of innovations
  - Success (fast growth, time to IPO) of start-ups, e.g. role of graduates for high growth innovation intensive firms
  - Productivity, growth, employment
- Effect of university quality on country wide innovation impact
  - Productivity and employment effects

Of course, any such analysis needs to control for other factors which affect the role of university outputs in innovative activity, or their effectiveness (see above, such as geographic proximity, distance to the frontier, etc.). Table 3 shows a selected collection of the literature according to this structure.

Table 3 **A review of the impact of university research quality on the effectiveness of university outputs for innovative activity**

Paper	Way of interaction	Findings: Role of quality	University output concerned
		Impact of quality on ….university outputs relevant for Innovation	
Agarwal und Ohyama 2013	Mobility university industry	Our model builds from the differences in the scientific production functions in academia and industry: basic scientists may work independently of applied scientists in academia, but have to work closely with applied scientists in industry. Because academic institutions make higher per capita investments in basic research relative to applied, our model generates some novel implications that are backed by the empirical analysis: in academia, scientists of higher ability sort into basic rather than applied research, and initial earnings of basic scientists are lower but the slope of their earnings is higher relative to applied scientists. In industry, by contrast, there is no such ability sorting, and the earnings trajectories of basic and applied scientists are similar.	Human resources
Carayol 2003	Academic engagement	The matching process in industry-science collaborative R&D preferably associates academics whose research excellence tend to be signalled as high (respectively, low), and whose research tend to be basic (respectively, more applied), with firms which are supporting a high (respectively, low) degree of risk (of research itself and its use in products and processes).	Knowledge
carayol and matt 2004	Patenting by public research institutions	Highly publishing labs also patent more.	Knowledge
Conti and Gaulé, 2011	Licensing of university inventions, TTO productivity	Differences in academic research (quality as measured by highly cited researchers), TTO staff and experience explain to a great extent the gap between the US and Europe in terms of the number of license agreements concluded.	Knowledge
Di Gregorio and Shane, 2003	University start-ups	The results show that intellectual eminence, and the policies of making equity investments in TLO start-ups and maintaining a low inventor's share of royalties increase new firm formation	Knowledge
Florida and Cohen, 1999	Good people attract good people attract good firms	Quality drives scientific labour market and student flows	Human resources
Perkmann et al 2013	engagement and commercialisation	survey of 36 articles: individual scientific productivity related positively to engagement and commercialisation, university or department quality related negatively to engagement, but positively to commercialisation	Knowledge
Perkmann et al., 2011	Academic engagement (Relational involvement with industry: collaborative research, contract research, consulting)	how the quality of university faculty is related to their industry engagement via collaborative research, contract research and consulting depends on discipline: in physcial&engineering - quality good for engagement (good and star researchers); in biological and medical sciences - star researchers negative, good researchers positive; social sciences quality is negative for engagement	Knowledge
Sine et al., 2003	Licensing of university inventions	Institutional prestige influences the number of licenses that a university annually generates over and above the rate that is explained by the university's past licensing performance.	Knowledge
Van Bouwel and Veugelers, 2012	Graduates	Top European PhD-students stay at high-quality US Economics Departments. Graduating from top department - signalling quality - graduates have much higher range of job opportunities.	Human resources
Van Bouwel and Veugelers, 2013	Graduates	quality of a country's higher education system drives macro-flows of foreign tertiary students in Europe. In human capital theory, individuals consider education as an investment decision. Students will bear the costs of higher education in order to increase their future earnings and employment opportunities. Students will prefer to attend a high-quality institution if any possible higher costs are compensated by higher returns.	Human resources
Van looy et al 2011	Contract research, spin-off, patenting. ontract research could be instrumental for creating spin off companies - might result in a better understanding of market potential and in the development of adequate business models.	A broader and more solid scientific base of universities implies more valorization opportunities. : scientific productivity positive for "entrepreneurial effectiveness" (contract research, spin off, patenting); no trade-off between transfer channels; contract research: firms that solicit academic partners for collaboration might favor scientifically prominent universities;more prolific scientists the ones who are more likely to patent. contract research and spin off activity turn out to be positively and significantly related.	Knowledge
Zucker, Darby, Torero 2001	Labour mobility university scientists firms	Higher quality scientists more likely to move to firms: As the quality of an academic star bio-scientist increases and his/her research becomes more relevant to commercialization, the probability increases that the scientist conducts joint research or moves to a firm. As expected scientific returns increase—measured by citations to other local star scientists working with firms—the probability that the next star will begin working with a firm also increases.	Human resources

table 3 continued

Paper	Way of interaction	Findings: Role of quality	University output concerned
		Impact of quality on... firm innovation process	
Abramovsky et al 2007	R&D co-location	Disproportionate co-location with highly rated univ. departments in pharmaceuticals: Proximity matters - scale/quality of univ research positive impact on economy: co-location of private sector-R&D lab with university research departments; exact nature of business-science link unknown (e.g., graduates? Consulting? Formal collaboration?); for machinery also univ department rated less than world-class important - applied public research also matters	Knowledge, human resources
Belderbos et al., 2009	Impact of quantity and quality of academic research on R&D location decisions by multinationals.	Quality attracts foreign R&D: number of relevant ISI publications by scientists based in the host country has a substantial positive impact on the propensity to conduct foreign R&D (=number of patents by multinational in host country). The effect is significantly larger for firms with a stronger science orientation in R&D - as indicated by citations to scientific literature in prior patents. firms that are leading in a technology field are attracted to academic research strengths, but much more strongly so if they are science oriented	Knowledge, human resources
Zucker et al., 2002	Research collaboration academic stars- firms.	A robust indicator of a firm's tacit knowledge capture (and strong predictor of its success) is the number of research articles written jointly by firm scientists and discovering, "star" scientists, nearly all working at top universities. Commercializing knowledge involves transfer from discovering scientists to those who will develop it commercially. New codes and formulae describing discoveries develop slowly - with little incentive if value is low and many competing opportunities if high. Hence new knowledge remains naturally excludable and appropriable. Team production allows more knowledge capture of tacit, complex discoveries by firm scientists.	Knowledge, human resources
Zucker, Darby, Brewer, 1998	Research collaboration academic star scientists and firm scientists	Location of top, "star" scientists predicts location of firm entry into new technologies (both new and existing firms); tacit complex knowledge of star scientists is scarce human capital around which firms are built or transformed (transfer through team organisation - collaborative research) scientific breakthroughs - complex tacit knowledge - natural excludability - firms can get built on it	Knowledge, human resources
Zucker and Darby, 2007	Research collaboration academic star scientists and firm scientists	highly cited academics are key for high tech entry in all of the S&T fields they are working in (5401 highly cited)	Knowledge, human resources
		Impact of quality on... firm innovation outputs and outcomes	
Narin et al, 1997	Citations of corporate patents to academic science papers	Public science is a driving force behind high technology and supporting US industry. Science that is contributing to high technology is mainstream, quite basic, quite recent, and published in highly influential journals.	Knowledge
Zucker, Darby, Armstrong 1998	Research collaboration academic stars- firms.	Research with stars leads to more innovation and commerical success: Ties that involve actual work at the science bench between star scientists and firm scientists consistently have a significant positive effect on a wide range of firm performance measures in biotech. Our findings on the importance of basic university science to successful commercialization of important scientific discoveries are confirmed in other research, especially the importance of intellectual human capital (Di Gregorio and Shane 2000). Faculty are a key resource in creating and transferring early, discovery research via commercial entrepreneurial behavior (Yarkin 2000). Jensen and Thursby (2001) confirm that active, self-interested participation of discovering professors is an essential condition for successful commercial licensing of university inventions.	Knowledge, human resources
Rothaermel and Thursby 2005	University spin-off	Strong ties to the sponsoring university reduce the likelihood of firm failure because of the strong intellectual property protection, quality signaling effect, and involvement of potential investors. Strong ties, however, retard graduation from the incubator. Weak ties, such as informal interaction with faculty, do not affect outright firm failure or timely graduation.	Knowledge, human resources

This review reveals that there is good evidence how university research quality affects the impact of university outputs on innovation inputs, but much less on innovation out- and outcomes. This is clearly an agenda for further research. Nevertheless, there are some robust links between university quality and innovation inputs, as outlined above. What are the mechanisms behind the impact of quality? These can only be hypothesised and will differ on a case by case basis:

- Reputation and signalling – university research quality can work as a signalling device for firms and graduates in an environment with significant information asymmetries (research quality can mostly only be assessed by researchers themselves), increasing trust and willingness to cooperate for firms and increasing graduates' future employment opportunities

- Talented researchers want to exploit their higher human capital through commercialisation (see, .e.g., di Gregorio and Shane 2003)
- Students want to increase their human capital (based on human capital theory, students think of education as an investment decision. They will bear the costs of higher education in order to increase their future earnings and employment opportunities. Students will prefer to attend a high-quality institution if any possible higher costs are compensated by higher returns
- Better, more groundbreaking research leads to more radical discoveries; high quality university patents are more likely to get commercialised through start-ups rather than through licensing (Shane, 2000, Sine et al., 2008)
- As regards the negative link between cooperation and university research quality, Agarwal - Ohyama, 2012; Thursby - Thursby - Gupta-Mukherjee, 2007 provide a possible explanation. The latter model tenure as a disincentive for risk averse faculty to conduct applied research prior to tenure. Basically, more applied work – which is likely to be the case in academic engagement (whereas academic commercialisation could also be based on pure basic research) has lower chances to get published, as general findings make it more easily into top journals than specific solutions to specific problems. Agarwal and Ohyama 2013 also find that talented researchers in academia sort themselves into basic research, whereas talented researchers in industry are equally likely to be involved in applied or basic research.

Discussion

The diagnostic of a European paradox, but also theories of the role of universities for innovative activities have led to a policy focus on improving the linkages of universities with firms, either through engagement or commercialisation activities, while the role of university quality – or research and teaching quality – has not received the same attention. In particular the Triple Helix literature often takes top US research universities as examples for the entrepreneurial role of universities in innovative activities, which have large budgets and excellent teaching and research faculty, managing to attract the best students from all over the world. Also the national innovation systems literature leads to a focus on cooperation and the linkages of universities with business, without stressing the conditions of effectiveness of such linkages. Point of this paper is not to say that this is wrong, but that this picture misses an important part of the story.

There needs to be something there in the first place which can be taught, read, transferred or commercialised, and it is not just quantity, but also quality which matters. Europe leads in quantity relative to the US, both in terms of graduates and publications and this shows up in academic engagement being more practiced in the EU than in the US, judging by bibliometric statistics, but also funding statistics of university research by industry point into the same direction. The US leads however clearly in quality and works as a consequence as a point of attraction for students and entrepreneurs from all over the world. good people (university academics) attract good people (good students) attract good firms (innovation-intensive ones, more likely to be keep their competitive edge (see Florida and Cohen, 1999). US universities topping the research impact rankings does matter for firm innovation.

As a result, is increasing research and teaching quality, strengthening universities' core missions of research and teaching, enough for boosting the potential contribution of universities to a new growth path? It is certainly a key aspect: When industrial research becomes increasingly science-based, the quality of academic research and of graduates increasingly matters as a crucial component of a future European growth model. "If nations and regions are really serious about building the capability to survive and prosper in the knowledge economy and in the era of talent, they will have to do much more than simply enhance the ability of the university to transfer and commercialise technology They will have to act on this infrastructure both inside and surrounding the university in ways that make places more attractive to and conducive to talent." (Florida - Cohen, 1999, p. 609)[3] However, increased production of better knowledge/graduates need to find their way into innovative activity. The question of linkage, of way of interaction remains relevant, as outlined by the triple helix and national innovation system literatures. As outlined above, however, efforts to increase research and teaching quality can alter the effectiveness of various interaction modes, as e.g. the literature on career concerns by top university scientists finds, that before tenure, they are unwilling to engage in applied linkages with firms, because they want to focus on excellent basic research, the publication of which assures tenure (Stern, 2004; Thursby - Thursby - Gupta-Mukherjee, 2007). So while firms generally want to relationally engage with high-quality universities, top research universities are more reluctant for this form of involvement in innovative activity, favouring placement of graduates and commercialisation of university discoveries as they come along with less compromises for the research agenda of top scientists, who are usually also well funded so depend less on additional industry funding. An illustration is MIT's policy towards firms contacting them to seek help for problems: just asking a question costs the firm USD 40.000, while in Europe, industry and university cooperation schemes are often heavily subsidised by public funding.

Declining willingness to engage in university-industry relationships once some universities become better in Europe need not be a concern for policy however, if policies aimed at increasing research and teaching quality work through competitive funding allocation mechanisms (and a reform of career and organizational structures, see Janger and Nowotny, 2013). In such mechanisms (see, e.g., Aghion et al., 2010a), vertical differentiation between universities results, i.e. differences in quality differentiate universities in terms of university specialization (Clark, 1983; Daraio et al., 2011). So there will be a greater number of top research universities in Europe, but still many applied universities which can focus inter alia on academic engagement. Here, the European Research Council certainly plays a welcome role, but at the Member State level much more needs to be done as evidenced by the various university rankings.

[3] A recent paper by Janger and Nowotny (2013) empirically identifiers drivers of job attractiveness in academia.

4. Conclusions

Policies towards business science links have recently been driven by the concept of the entrepreneurial university. However, efforts to increase the entrepreneurship of universities have seldom targeted the first two mission of universities, research and teaching. Any entrepreneurship can only be as strong as the quality of research and teaching. Based on a conceptual model of universities' role in innovative activity and a review of the evidence, this paper has tried to argue that a narrow focus on linking universities with firms and society without making sure that universities' first two missions - research and teaching - work well is an ineffective approach towards increasing the contribution of universities to innovative activity, and hence to a new growth path.

We recommend focusing on improving the performance of European universities in their first two missions rather than trying to improve the third mission – directly contributing to economic development, through, e.g. commercialization - without a sufficient foundation in knowledge creation and distribution. A socio-ecological transition needs the best science it can get: the scale of scientific and technological challenges involved with this transition is daunting, while the returns to academic research are higher the more difficult the problem at hand. At the same time, we highlight the pitfalls of only using models of the role of universities in innovation systems, such as e.g. the triple helix concept, which only look at specific contributions of universities for innovative activities and mostly do not consider the conditions for the effectiveness of proposed ways of interaction, such as the necessary quality of the science base for valorization activities (see also Leten - Landoni - Van Looy, 2014, who make a similar point). In particular, the role of universities in training graduates who then move on to innovative activities within firms is often not stressed enough.

Our main findings of our review of the relevant evidence are that university quality positively affects in particular flows of graduate students and academic commercialization, whereas excellent basic research is potentially negatively related to academic engagement such as collaborative R&D. Research (and teaching) quality is crucial for attracting good students (see also Florida and Cohen, 1999). In terms of policies, this implies that Europe should actively foster the quality of its universities, e.g. through competitive funding and attractive career and organizational structures in open academic labour markets (see Aghion et al., 2008, 2010a; Janger - Nowotny, 2013; Janger - Strauss - Campbell, 2013).

Competitive funding and recruitment policies will lead to increased vertical differentiation of the European university landscape (see, e.g. Daraio et al., 2011) so that top basic research universities can attract top students and researchers, while more applied universities can stimulate firm performance through academic engagement (collaborative R&D, contract research and consulting). Linkages for top research universities work more through mobility of scientists and graduates, as well as through commercialization (licensing technologies or setting up spin-offs), linkages for applied universities work more through academic engagement. In top research universities, new commercialization instruments may be necessary, such as university-internal organizations which bring university discoveries or technologies closer to the market (as practiced, e.g., by the Harvard Accelerator, or at the University of Maryland).[4]

Of course, any policies aimed increasing universities' role in a new growth path need to take account of many issues influencing their effectiveness, such as the distance to the technological frontier which asks for accordingly variable institutions, which is particularly important for the heterogeneous EU; but also other issues come to mind, not least industrial specialization, peculiarities of national higher education systems etc.

4 See http://www.mtech.umd.edu/va/ and http://otd.harvard.edu/accelerators/

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Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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