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The contribution of universities to innovation, (regional) growth and employment

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The contribution of universities to innovation, (regional) growth and employment

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Executive Summary

The main objective of this study is to provide a review of the literature and evidence on the contributions of universities to innovation and employment. While teaching and research are the first and second stream of activities of universities, a third stream of activities is the ***contribution of universities to society*** by transferring their know-how. This third stream of activities builds upon the first and second, but it is increasingly being seen as important and distinctive in its own right, deserving of specific policies and resources to ensure their effective functioning. This line of activities is the main subject of this report: are European universities, through their third stream of activities, able to match society's expectations as engines of innovative growth and achieve their full potential, without jeopardizing their main mission of educating and basic research?

In order to better understand how European universities can and should develop their third mission of contributing to society in harmony with their first and second mission, we first look at the economic frameworks that help understanding the impact of universities on economic growth and innovation. Both endogenous growth theory and the Triple-Helix concept of university-industry-government interactions emphasize the role of universities in not only creating ideas but also transferring them towards commercial uses. Then, we review the macroeconomic and microeconomic evidence that exists on the contribution of universities to growth and innovation. Overall, there is strong evidence of complementarity between publicly funded research (mostly taking place at universities) and private investment on R&D and corporate innovation. However, the literature also emphasizes the large time lags required, the importance of the innovative system's position relative to the technological frontier, the restriction of these positive effects to specific subsets of technological fields and the importance of geographic proximity. The link between science and industry is therefore neither direct nor obvious. This motivates a deeper look into the factors that prevent transfers from science to technology: inadequate intellectual property right regimes, poor incentive schemes, or the lack or deficiency of dedicated organizational structures for technology transfer.

What are then the channels through which university research may contribute to innovation? Best-known success stories of licensing of universities patenting and spin-offs, while important, tend to divert attention away from perhaps the most important channel: the mobility of

university trained students and researchers. It is unfortunate that hampered by data availability, research on this pathway remains relatively scarce.

We also look into the role of universities as economic actors having a direct and indirect effect on (local) jobs and GDP as well as their contribution to regional or local development. Once again, the major focus in most studies on the contribution of universities to regional development is on technology transfer, more particularly patenting, licensing and spin-offs, all tending to show a strong Alma-Mater home bias. There is strong evidence that knowledge spillovers are geographically localized. The empirical literature that evaluates the role of science parks and incubators and the role of universities in the formation of technology clusters is still in its infancy and weak in testing for causation. But also the first teaching mission of universities may lead to strong regional effects, as some in-moving students stay in the area after graduation. In addition, there are other pathways for universities to contribute to regional development: enabling industrial change, the integration of previously separate areas of technological activity, attracting new knowledge or financial resources from elsewhere… Thus, the one-size-fits-all approach to economic development through spin-offs and licensing which so many universities have been pursuing needs to be opened for multiple pathways.

Executive Summary (GERMAN)

Diese Studie gibt einen Überblick über die Literatur und die empirische Evidenz zum Beitrag von Universitäten zu Innovation und Beschäftigung. Während Lehre und Forschung die erste und zweite Hauptaufgabe von Universitäten sind, ist eine dritte Aufgabe ***der gesellschaftliche Beitrag von Universtäten***, indem sie Wissen bereitstellen und in die Öffentlichkeit tragen. Diese Aufgabe baut auf den beiden Hauptaufgaben auf, wird aber als immer wichtiger betrachtet und entwickelt sich zu einem eigenständigen Tätigkeitsfeld, zu dessen Erfüllung spezifische Grundsätze und Ressourcen garantiert werden müssen. Dieses dritte universitäre Aufgabengebiet ist das Hauptthema dieses Berichts: Sind europäische Universitäten fähig, die gesellschaftlichen Erwartungen, Motor für innovatives Wachstum zu sein, zu erfüllen und können sie ihr volles Potential entfalten, ohne ihre anderen beiden Hauptaufgaben, Lehre und Grundsatzforschung zu vernachlässigen?

Um besser zu verstehen, wie europäische Universitäten ihr drittes Aufgabengebiet, den gesellschaftlichen Beitrag, gleichzeitig mit dem ersten und zweiten Aufgabengebiet voranbringen können und sollten, betrachten wir zuerst den ökonomischen Rahmen zur Rolle von Universitäten für wirtschaftliches Wachstum und Innovation. Sowohl endogene Wachstumstheorie als auch das Triple-Helix Konzept zur Wechselwirkung von Universitäten, Industrie und Regierung betonen, dass die Rolle von Universitäten nicht allein darin besteht, Ideen zu entwickeln, sondern auch darin, diese für die kommerzielle Nutzung übertragbar zu machen. Anschließend fassen wir die makro- und mikroökonomische Evidenz zum Beitrag von Universitäten zu Wachstum und Innovation zusammen. Es gibt starke empirische Belege für die Komplementarität zwischen öffentlich finanzierter Forschung (welche hauptsächlich an Universitäten stattfindet) und privaten Investitionen für Forschung und Entwicklung und Innovation durch Unternehmen. Die Literatur betont gleichzeitig, dass die Komplementaritäten nur mit großer zeitlicher Verzögerung beobachtet werden können und dass der Abstand des innovierenden Systems zum Technologieführer eine Rolle spielt. Der positive Zusammenhang wird außerdem nur in bestimmten technologischen Feldern gefunden und wird von geographischer Nähe beeinflusst. Dies zeigt, dass der Zusammenhang zwischen Wissenschaft und Industrie weder direkt noch offensichtlich ist. Deshalb werden die Faktoren, die einen Transfer von der Wissenschaft in die Industrie erschweren, näher beleuchtet: unangemessene

intellektuelle Eigentumsrechtsregime, schwache Anreizsysteme oder das Fehlen bzw. der Mangel an organisatorischen Strukturen für den Technologietransfer.

Durch welche Kanäle kann universitäre Forschung zu Innovationen beitragen? Bekannte Erfolgsgeschichten über die Lizensierung von Universitätspatenten und universitären Ausgründungen sind zwar wichtig, lenken die Aufmerksamkeit aber von dem wahrscheinlich wichtigsten Kanal ab: der Mobilität von Studierenden und Forschern. Leider ist die Forschung zu diesem Thema durch Datenmangel beschränkt und deshalb eher rar.

Außerdem betrachten wir Universitäten als ökonomische Agenten, die sowohl eine direkte als auch eine indirekte Auswirkung auf das (lokale) Stellenangebot und das BIP haben und zur regionalen oder lokalen Entwicklung beitragen. Auch hier liegt der Schwerpunkt der meisten Studien auf dem Technologietransfer, besonders auf Patentierung, Lizensierung und Ausgründungen, wobei alle Studien einen starken Heimatuniversitätsbias finden. Es gibt überzeugende Belege, dass Wissens-Spillover geographisch beschränkt sind. Die empirische Literatur zur Rolle von Wissenschaftsparks oder Inkubatoren und der Rolle von Universitäten bei der Bildung von Technologieclustern steht noch am Anfang und hat Schwierigkeiten, kausale Zusammenhänge nachzuweisen. Aber auch die erste Aufgabe von Universitäten, die Lehre, kann zu starken regionalen Effekten führen, da manche zugewanderten Studierende nach dem Abschluss in der Gegend bleiben. Außerdem gibt es weitere Wirkungspfade, über die Universitäten zur regionalen Entwicklung beitragen können: Sie können industriellen Wandel ermöglichen, zuvor getrennte Gegenden mit technologischer Aktivität verbinden, neues Wissen und finanzielle Ressourcen anziehen … . Deshalb muss der Einheitsansatz vieler Universitäten, ökonomische Entwicklung durch Ausgründungen und Lizensierung voranzutreiben, für eine größere Vielfalt an Wirkungskanälen geöffnet werden.

Executive Summary (FRENCH)

L'objectif principal de cette étude est de réviser la littérature et les données empiriques disponibles sur la contribution des universités à l'innovation et l'emploi. Alors que l'enseignement et la recherche sont les principales activités des universités, un nouveau courant est apparu sous la forme du transfert de savoir-faire vers la société. Ce troisième volet des activités universitaires s'appuie sur les deux premiers, mais on le considère plus en plus comme aussi important et original; il en vient donc à mériter une politique d'appui et des ressources propres pour assurer son bon fonctionnement. Cette ligne d'activités est le sujet principal de ce rapport qui prétend répondre à la question suivante: les universités européennes sont elles, à travers de cette activité de transfert, en mesure de répondre aux attentes de la société en tant que moteur de croissance et source d'innovation? Sont elles à même de réaliser leur plein potentiel, sans pour autant compromettre leur principales missions que sont l'éducation et la recherche fondamentale?

Afin de mieux comprendre comment les universités européennes peuvent et doivent développer cette troisième mission de transfert sociétal en harmonie avec ses premières missions, nous examinons tout d'abord les théories économiques qui nous permettent d´appréhender l'impact des universités sur la croissance économique et l'innovation. La théorie de la croissance endogène et le concept de triple hélice des interactions université—industrie—gouvernement insistent sur le rôle des universités, non seulement dans la création des idées mais aussi sur leur transfert à des fins commerciales. Dans un second temps, nous passons en revue les données macroéconomiques et microéconomiques qui existent quant à la contribution des universités à la croissance et à l'innovation. Dans l'ensemble, nous observons des preuves solides de complémentarité entre recherche publique (principalement développée en université) et investissement privé en R&D et aussi vis-à-vis de l'innovation au sein des entreprises. Cependant, la littérature note l'existence d'un long décalage temporel nécessaire pour le transfert technologique. De plus, on doit souligner l'importance du positionnement du système d'innovation par rapport à la frontière technologique, mais aussi le fait que ces effets positifs ne s'appliquent qu'à des domaines technologiques bien spécifiques et finalement, le poids de la proximité géographique. Le lien entre la science et l'industrie n'est donc ni direct, ni évident. Ceci nous conduit à étudier en profondeur les facteurs qui empêchent le transfert de la science vers la technologie, comme par exemple la faiblesse des régimes de propriété intellectuelle, de

mauvaises incitants au sein du système, ou encore l'absence (et/ou l'insuffisance) de structures organisationnelles dédiées au transfert de technologie.

Quelles sont alors les voies par lesquelles la recherche universitaire peut contribuer à l'innovation? Les réussites les plus spectaculaires de brevets obtenus par les universités ou de lancement de spin-offs, malgré leur importance, ont tendance à détourner notre attention du vecteur de transfert qui pourrait se relever être le plus fondamental: la mobilité des diplômés universitaires et des chercheurs. Il est regrettable que, entravée par l'indisponibilité des données, la recherche dans cette voie reste relativement rare à l'heure d'aujourd'hui.

Nous examinons également le rôle des universités en tant qu'acteurs économiques ayant un effet direct et indirect sur l'emploi et l'activité économique locale ainsi que leur contribution au développement régional. Une fois de plus, nous observons que la plupart des études sur la contribution des universités au développement régional se centrent sur le transfert de technologie, et plus particulièrement les brevets, les licences et les spin-offs. L'évidence empirique montre que les externalités de connaissances sont localisés géographiquement autour des Alma-mater. La littérature empirique qui évalue le rôle des parcs scientifiques, des pépinières d'entreprises et le rôle des universités dans la création d'agglomérations d'entreprises technologiques (cluster) est encore balbutiante et présente des tests de causalité très faibles. Il faut aussi remarquer que la première mission des universités, l'enseignement, peut conduire à de forts effets régionaux, puisque de nombreux élèves nouveaux venus restent dans la région après l'obtention de leur diplôme. En outre, il existe d'autres voies par lesquelles les universités contribuent au développement régional, en permettant les mutations industrielles, l'intégration de secteurs technologiques précédemment isolés les uns des autres, en attirant de nouvelles connaissances ou des ressources financières extérieures, etc... Ainsi, l'approche «taille unique» du développement économique à travers les brevets et les incubateurs, que de si nombreuses universités ont poursuivis, a montré ses limites; il faut donc ouvrir de nouvelles voies.

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1. INTRODUCTION

As European economies worry about their economic recovery and future prospects in a rapidly changing world economy, their attention naturally turns to universities, sources of two most valuable assets for economies: educated, skilled people, and new ideas. Through their teaching, universities disseminate knowledge and improve the stock of human capital; through the research they perform, universities extend the horizons of knowledge; and by their third-mission activities, they transfer their knowledge to the rest of society, work with industry and create the seeds that lead to new companies.

While this third stream of activities builds upon the first (education) and second (research), it has not been 'core' in the same way as the first two streams of university activity. However, these 'third stream' or 'third mission' contributions are increasingly seen as important and distinctive in their own right, deserving of specific policies and resources to ensure their effective functioning. Nowadays, universities are demanded not only to play an active role in education and science and technology development, but also increasingly to turn those scientific developments into useful innovations whenever possible and desirable. Throughout the world, governments – national, regional and local – are seeking ways to strengthen the "third stream" role of universities as agents of innovation based growth, looking for a more direct and larger-scale involvement of universities in knowledge transfer than ever before (Geuna & Muscio 2009). Some speak of a 'second academic revolution' that took place in the 1990s, adding entrepreneurial objectives as a third component to the mission of the university (Etzkowitz, Webster and Healy, 1998) and introducing the concept of "entrepreneurial" universities. ''The entrepreneurial university integrates economic development with the university as an academic function along with teaching and research. It is this ''capitalisation of knowledge'' that is the heart of a new mission for the university, linking universities to users of knowledge more tightly and establishing the university as an economic actor in its own right'' (Etzkovitz, 1998, p. 833).

The rising interest in the university's economic development role has been fueled by high profile examples of successful regional economies in which the university contribution is clear, such as

Silicon Valley, the Boston area, and the region around Cambridge in the UK. Similarly widely known are cases of 'blockbuster' licenses on university developed and patented technology, such as Stanford's non-exclusive license on recombinant DNA. The university origins of enormously successful companies like Cisco, Google, and Yahoo (all three of which grew out of Stanford University research and two of which took Stanford licenses) are well known. These success stories have helped to promote what has now become a standard view of the entrepreneurial university and its economic role, centering on technology transfer, more particularly (licensing) patents and faculty spin-offs.

For university administrators, the new focus on this 'third stream' mission of economic growth has generally been a welcome development, in part because of its promise of new revenues at a time when traditional revenue sources are under increasing pressure. But working ties to the operating sectors of the economy are not central to the internal design of the university as an institution.

As universities open themselves up to the marketplace for knowledge and ideas to a greater degree than in the past, debates over university missions has been common, and a whole literature has spun around the impact of the increasing attention towards the university third mission on its core first and second mission, see eg Foray and Lissoni (2009) "managing a trade-off between two good things: getting more academic knowledge used by the economy versus maintaining the fundamental missions (long-term research and education) of universities" or a more critical Feller (1990): "Increased efforts by universities to foster the commercialization of technological innovations erodes the singular position of institutions of higher learning in the United States". "These ventures also serve to shift academic researchers from the social roles in which they are most efficient, as suppliers of a collective good: scientific and technological knowledge."

Overall, the empirical analysis has not yet come up with robust evidence supporting crowding out of the first and second missions. The most successful universities seem to excel in all three missions, exploiting the complementarity between them: teaching, research and tech transfer (see eg Van Looy et al (2004); Van Looy et al (2011)). The challenge for universities is to find ways to cope with their multi-tasking, i.e. how they reconcile teaching, the "exogenous" (i.e.

curiosity-driven invention) and "endogenous" (i.e. market-driven innovation) component of the academic research and knowledge transfer.

Are European universities able to match society's expectations as engines of innovative growth and achieve their full potential, without jeopardizing their main mission of educating and basic research? To better understand how European universities can and should develop their third mission of contributing to society in harmony with their first and second mission, this report first looks at the economic frameworks that allow to study the impact of universities on economic growth and innovation (chapter 2). The macroeconomic and microeconomic evidence that exists on the contribution of universities to growth and innovation is reviewed in chapter 3. Chapter 4 zooms in on the mechanisms and institutions that may help to stimulate the third mission activities of universities. Intellectual property right regimes, incentive schemes and technology transfer offices are examined in this chapter. Chapter 5 looks more carefully at the different pathways through which universities impact innovation and growth. To this end it not only looks at university patenting and faculty spin-offs, but also includes other pathways, most notably the human capital component of training of graduates and researchers. Chapter 6 looks at how universities as economic actors have a direct and indirect effect on (local) jobs and GDP. Chapter 7 looks at the contribution of universities to regional or local development. Chapter 8 looks at the evidence on which policy instruments are most promising for improving universities contribution to growth and innovation.

The report mostly looks at the contribution of universities to economies through affecting the innovation component of growth. This is also the area where most evidence and analysis can be found. In view of the pivotal role of the jobs-agenda for Europe, we will also discuss the contribution of universities to jobs, but mostly through the lens of innovation based employment. Special attention will be devoted to job creation through higher-education based entrepreneurship, university spin-offs but also new business formation by graduates. We will also include the direct contribution of universities as employers, as well as the indirect employment creation around universities.

2. FRAMEWORKS FOR ANALYSING THE CONTRIBUTION OF UNIVERSITIES TO INNOVATION

A multitude of economic studies have shown the importance of basic research for technology, innovation and economic growth (e.g. Allen, 1977; Tushman, 1977; Tushman & Katz, 1980; Jaffe, 1989, Adams, 1990, Narin et al 1997, Griliches, 1998, Rosenberg & Nelson 1994; Mansfield, 1995; Henderson et. al. 1998; Branscomb et al., 1999, Cohen et al 2002). The technology management literature has documented the process of how scientific knowledge feeds into successful innovations and consequent economic growth mainly on the basis of specific case studies and detailed surveys at the firm-level (e.g. project Hindsight, 1958, project TRACES, 1967; Tushman, 1977; Tushman & Katz, 1980; Bud, 1994; Hills, 1997). However, a coherent body of theory and insight into the multifaceted nature of the links between science and markets is still lacking (Stephan, 1996). How the assess the nature and impact of knowledge externalities from universities? Knowledge externalities from universities may arise either when private or public research builds on existing university research or from human capital spillovers when working with university graduates.

There are basically two main frameworks used in the literature to analyse the contribution of universities to innovation through assessing the nature and impact of knowledge externalities. These are (i) endogenous growth theory and (ii) the National Innovation Systems/Triple Helix. The next two sections will give a short overview of these two frameworks.

2.1. Endogenous growth theory

The theory of endogenous growth, pioneered by Romer (1990), Aghion and Howitt (1992) and Grossman and Helpman (1991) provides a theoretical framework to understand the relationship between education, basic research and growth.

Box 1: A short digression into endogenous growth theory

Romer (1990) describes and economy that focuses on production and innovation. There are two production sectors: intermediate goods, such as machinery and equipment, chemicals or electronics, which are used to produce the final goods. The end consumer only buys final goods, but these embody intermediate goods as inputs. The broader the variety of inputs available, the most cost effective it is to produce one unit of final good.

Invention is the process through which new intermediate goods appear in the economy. Economic growth thus results from inventions made available in the economy, which in turn allow the production of more final goods with the same numbers of hours worked. This process of increasing productivity continuously increases wages, investment, and GDP along a balanced growth path.

However, innovation is a costly activity. It requires ex ante investment in research and development. Firms volunteer this investment only if they can recoup their costs through future profits. Inventions must be protected, e.g. with patents, in order to ensure a subsequent flow of profits when an innovation translates into production. Research and development is typically an activity that uses educated labour, the so called "human capital", as an input. Moreover, production and innovation are two sectors that compete for the educated labour force: more innovation generates growth in the long run, but reduces production in the short run. How human capital divides between these two activities depends on market forces. Two other important results of Romer are:

1. that innovation generates a positive externality: the innovative firm cannot capture the social benefits of its patents fully, and therefore underinvests in R&D. In his setup, appropriate subsidies to R&D are thus needed to maximize welfare;
2. that an increase in human capital –a better educated labour force– allows for faster innovation and therefore faster economic growth. A similar effect can be reached by pooling together the human capital resources of different countries, which justifies the efforts by the European institutions to spur student exchanges and create a European-wide labour market.

Aghion and Howitt (1992) and Grossman and Helpman (1991) challenge Romer's theory. They emphasize that innovation also has a Schumpeterian "creative destruction" effect, in the sense that some innovations actually replace old technologies. Therefore, for a part, innovation exerts a negative externality on the incumbent producers of intermediate goods. For this reason, there is a theoretical possibility that firms overinvest in innovation: the innovation process becomes too fast, and economic growth could be reduced due to creative destruction

Further work by Acemoglu et al. (2006), Aghion et al. (2006) and Vandenbussche et al. (2006) highlight the presence of a "technology frontier" that affects how innovation processes operate. When a firm or a sector in a country is distant from the technology frontier, climbing up the quality ladder through product or process innovations requires an investment in some sort of "imitation" activities. That is, a firm that is lagging behind must identify which parts of a leading firm's product or production process makes it productive or profitable. Understanding this, and adapting it to one's own firm/sector, clearly requires knowledge, human capital, and a specific form of research and development that can prove very profitable: a firm can more easily adapt existing technologies than invent new ones.

Closer to the technology frontier the innovation process becomes different. It requires a deeper mastering of technology, as well as investment in research activities that are more difficult, costly, and that yield more uncertain outcomes.

The majority of studies based on endogenous growth theory (see Box 1) suggests that a key role in economic development is played by technological progress and the commitment of resources to innovation. In general, studies in this vein have focused primarily on the impact of private sector R&D or R&D as a whole. Only a few studies single out the impact of universities.

Particularly at the frontier of technological progress, the connection with fundamental research, typically done in universities becomes crucial. The type of human capital needed to pursue frontier pushing research is also different: genuine "inventors" are needed. Often, such inventors come from or are closely linked to fundamental research in universities. Their productivity in the invention process depends on the quality of their education.

Vandenbussche et al. (2006) propose an extended model of endogenous growth to capture these effects. Within the innovation sector, they draw a distinction between innovation and imitation activities, and incorporate in their model the important fact that innovation requires more human capital (education) than imitation. Making use of these results, they study the impact of an increase in the education level. They show that investing in higher education (high skills) "*enhances productivity growth all the more the economy is closer to the world technological frontier*.

New growth theory models are important as they see human capital as an important input in the creation of new ideas, and this mechanism provides a relevant justification for education as a central determinant of growth rates, even over long time intervals.

In most endogenous growth models based on research and development, the stock of human capital is taken to be exogenously determined. Later papers, notably Acemoglu (1997), have relaxed this assumption, and considered what happens when individuals can choose to make investments in education or training, while firms make investments in R&D. For some parameter values, multiple equilibria are possible, since the incentives of workers to invest in human capital, and those of firms to invest in R&D, are interdependent. This provides a way of formalising earlier ideas about the possible existence of a "low-skill, low-quality trap" in which low skill levels and slow rates of innovation reflect a co-ordination failure. The models suggest that, at the aggregate level, greater investment in education or training might raise expenditure on private R&D, and vice versa.

2.2. NATIONAL INNOVATION SYSTEMS AND THE "TRIPLE HELIX"

The concept of 'innovation systems' has gained widespread acceptance since the mid-1980s. The "innovation systems" approach stresses the role of, and the interplay between, different types of innovation actors for understanding the dynamics behind innovative performance, growth and competitiveness of nations (e.g. Freeman, 1987, 1991; Adams, 1990; Lundvall, 1992; Nelson, 1993; Mowery and Nelson, 1999; Baumol, 2002). The pivotal role of universities in innovation systems can also be found in the literature on the 'Triple Helix' concept of university-industry-government interactions, which rose to prominence in the second half of the 1990s (Leydesdorff and Etzkowitz, 1998; Etzkowitz and Leydesdorff, 1997).

In these models, universities are considered as relevant and distinctive actors, contributing to the innovative potential of societies. This holds particularly for basic research, which is characterized by high levels of technological and market uncertainties and long lead times. Private investors tend to refrain from basic research, leaving universities and public research institutes uniquely positioned to produce science-based knowledge upon which the development of new products, processes and services can build.

At the same time, an effective contribution to the capacity of an innovation system requires that universities not only create ideas that can be commercialized, but also that they are willing to become involved in the process of transferring research ideas towards commercial success. The notion of 'entrepreneurial universities' (Branscomb, Kodama & Florida, 1999; Etzkowitz, Webster & Healy, 1998, Etzokowitz, 1998) refers to universities becoming more active in the transfer of research results. There are various pathways for industry and science to interact. These include formal relationships, such as collaborative agreements between science and industry, R&D contracting, own licensing policies and intellectual property management and spin-off activities of science institutions. But behind this multitude of formal relationships lies a myriad of informal contacts, gatekeeping processes, personnel mobility and industry-science networks on a personal or organizational base. These informal contacts and human capital flows are ways of exchanging knowledge between enterprises and public research – creating spillovers - and are more difficult to quantify, but nevertheless extremely important and often a catalyst for instigating further formal contacts.

Companies – in employing more open innovation strategies (Chesbourgh 2003) have been looking more closely at university laboratories as contributors to their research and product development activities. Academic research informs the methods and disciplines employed by firms in their own R&D facilities. Firms that rely on scientific research findings are able to develop a deeper understanding of the technological landscapes in which they search for new inventions. It allows them to better anticipate, evaluate and translate the outcomes of their technology activities (Rosenberg, 1990; Fleming and Sorenson, 2004).

There are some industries where the link between science and innovation is explicit and direct. Industries such as biotechnology, pharmaceuticals, organic and food chemistry are "science-based" in the classic sense and rely heavily on advances in basic research to feed directly into their innovations (Levin et al. 1987). In non-science based industries much innovation also derives from other-than-basic-research related activities. Nevertheless, even here innovation may be facilitated by better use of basic research resources, such as the training of skilled researchers helping to increase the absorptive capacity of industry (for more of this, see infra section 7.4).

3. EVIDENCE ON THE CONTRIBUTION OF UNIVERSITIES TO INNOVATION AND GROWTH

3.1. MACROECONOMIC-EVIDENCE ON THE CONTRIBUTION OF UNIVERSITIES TO INNOVATION AND GROWTH

Empirical studies using the spirit of endogenous growth theory seldomly look at the impact of universities in particular. A series of studies focus on measuring the impact of publicly funded research. As this publicly funded research in most cases reflects to a large extent university funded research, we will review this empirical evidence in this section. Two strands of studies can be identified: those that measure the impact on productivity growth and those that measure the impact on private R&D. Most of these studies grapple with establishing a causal link from university research to private R&D and growth. They should therefore be mostly interpreted as providing correlative evidence.

3.1.1. Impact of publicly funded (university) research on (total factor) productivity growth

When empirical studies in the spirit of endogenous growth theory perspective attempt to separate out the economic impact of university or publicly funded research on (total factor) productivity growth, a large positive association is usually identified (e.g. Lichtenberg, 1993, Coe and Helpman, 1995). Guellec and van Pottelsberghe de la Potterie, 2004 provides an analysis for 15 OECD economies in the period 1980-1998. The authors calculate measures of the total public R&D capital stock stemming from R&D performed in the public sector (which includes the higher education sector and the government sector). They estimate a long-term responsiveness (elasticity) of multi-factor productivity with respect to public research that is positive and higher than the response to private sector research (the long run elasticity, or 'responsiveness', being 0.17 for public compared to 0.13 for private). This reflects that publicly funded research is more concerned with basic research and is associated with a higher degree of spillovers to the rest of the economy. They also show that the responsiveness of multi-factor productivity with respect to public sector research is higher when business R&D intensity in the economy is higher. This emphasises the complementarity between public research and investment in the business sector.

Without absorptive and innovative capacity in the business sector, the ability to capitalise on opportunities arising from public research will be limited. This highlights the essential importance of considering the impact of public sector research along with complementary investments by other sectors of the economy. Guellec and van Pottelsberghe de la Potterie (2004) also show that the impact of public sector R&D is positively affected by the proportion accounted for by university research. This is not the case for public sector laboratory research. They speculate that government performed R&D may be more focused on targeted areas, such as public health, environment and defence issues, and hence is less likely to directly impinge on measured GDP growth. Finally, the impacts are achieved within a three-year periods. These time lags appear remarkably short, compared to the findings from micro-analysis (cf infra).

There have been a number of attempts to estimate the impact of public sector funding on public sector R&D at the level of individual sectors or fields of research. Most of these studies were US based, with the early ones often being concerned with agricultural research. A recent study analyzing the impact of university research on agricultural productivity in the US is Kantor and Whalley (2013). Analysing county-level agricultural census data from 1870 to 2000, they conclude that farm productivity declines with distance from university research, and that, while average proximity effects disappear after 30 to 50 years, they still remain today in those stations that focused on basic research. Also in the industry studies reviewed in Salter and Martin (2001), the effects occur with long time lags. Although these time lags appear to be shortening over time, they still fall within the range of at least six to 15 years.

3.1.2. Impact of publicly funded (university) research on private R&D

An important pathway through which universities impact growth is through innovation and private R&D. Recent studies focus on the nature of the relationship between public and private sector R&D and whether they are complementary or tend to substitute for one another. These studies provide further evidence of the positive impact of public sector R&D on private sector R&D. In particular, public research is critical to industrial R&D in a small number of industries but has important effects across a much wider range of sectors. In addition, publicly funded expenditure on R&D has a positive impact on private sector R&D and on the number of R&D personnel employed in the business sector. This strongly reinforces the hypothesis of complementarity between business and public sector R&D (Cockburn & Henderson, 2001; Cohen, Nelson & Walsh, 2002).

Cincera et al. (2009) develop an empirical methodology for assessing the efficiency of the main policy instruments open to governments to support R&D activities in the private sector. They distinguish between direct subsidies and tax incentives as supporting policies alongside R&D performed in the public sector. Within public research, they also distinguish between the higher education and government sectors. Using stochastic frontier analysis, they show that expenditures on R&D at higher education institutes have a positive and significant impact on private sector R&D and on the number of R&D personnel employed in the business sector.

Aghion et al. (2009) try to carefully assess the causal link between public expenditures at universities and growth for US states. They find that research universities are more growth enhancing in states that are closer to the technological frontier. For a state far from the technological frontier, a thousand dollars of research education-type spending per person in the cohort decreases growth by 0.07 percentage points, suggesting that the shock either induces migration or crowds out more productive expenditures. They show that innovation in the private sector is a very plausible channel for externalities from research and four-year college type education. For a state at the technological frontier, a thousand dollars of research education-type spending per person in the cohort raises patents per person by 6 per 100,000). But, in a state far from the technological frontier, an exogenous thousand dollar investment in any type of higher education has no discernable effect on patenting.

3.2. THE CONTRIBUTION OF UNIVERSITIES TO CORPORATE INNOVATION: MICRO-EVIDENCE

Empirical evidence from firm surveys (Mansfield, 1995 & 1997; Cohen et al, 2002, Veugelers & Cassiman 2005) confirms the importance of university research for corporate innovation performance. Various proxies are used to quantify knowledge transfers from academia. Shane (2002) investigated licensing of university generated innovations. Other papers have examined academic spin-off activities (Shane 2002, Zucker et al. 1998; Audretsch & Stephan 1996; Utterback et al, 1983). Henderson et al. (1998) looked at citations to academic patents, Siegel et al. (2003) at university science parks, while a paper by Branstetter (2003) uses citations in corporate patents to scientific literature.

All these empirical studies using various industry science links indicators, suggest an intensification of the interactions between universities and industry over time. These links are highly concentrated in a small subset of technological fields (cf supra). They also often remain geographically restricted (Jaffe, Trajtenberg & Henderson 1993; Audretsch & Stephan (1996)).

In this empirical literature university-industry collaborative research has received substantial attention (Hall, Link & Scott 2000; Cockburn & Henderson 2001; Mohnen & Hoareau 2003; Belderbos et al, 2004; Veugelers & Cassiman 2005). Most of this literature focuses on which companies are engaged in industry-science R&D cooperation. These are typically larger firms, and firms in science based industries (like biopharmaceuticals and ICT). These are also firms with a stronger own R&D capacity, as an own absorptive capacity is needed to turn the link with science into improved innovative performance (cf supra). Also firms with a wider set of collaborative partners in their industry are more likely to be collaborating with science, indicating the importance of a network of partners to exploit complementarities between different types of R&D collaborations (Veugelers & Cassiman 2005). Also Belderbos et al (2004) find that spillovers received from universities not only stimulate collaboration with universities, but also R&D collaboration with other partners.

Studies on the effects of cooperation with universities on participating firm's innovative performance, most of them using European CIS data, show positive effects for cooperating firms (eg Monjon & Waelbroeck (2003), Tether (2002)). Belderbos et al (2004) distinguish between the various types of R&D partners to assess the effects on performance (innovative performance as well as productivity growth). They find that cooperation with universities is instrumental in creating innovations generating sales of products that are novel to the market, improving the growth performance of firms. This is in contrast with other types of cooperation which only have an effect on incremental innovations, rather than more drastic innovations.

3.3. RESEARCHER MOBILITY AS PATHWAY FOR KNOWLEDGE SPILLOVERS FROM UNIVERSITIES TO INDUSTRY: MICRO-EVIDENCE

Researchers' mobility is a critical mechanism to transfer knowledge from the university to industry, particularly when the knowledge to be transferred is hard to codify, which is typically the case for science-based knowledge. Although this is an area of great importance to the study of the innovation process, only recently research has started to attempt to trace labour mobility. Most of this research is concentrated on mobility between firms and, mostly using patent information, focusing on the mobility of inventors. By and large, this literature confirms the importance of inter-firm mobility of inventors as pathway for knowledge spillovers. Almeida and Kogut (1999) apply the methodology of Jaffe et al. (1993) to investigate for the semiconductor industry in the US the spatial character of knowledge externalities. Their analysis suggests that a driving force for local externalities in this case is the inter-firm mobility of patent holders. Rosenkopf and Almeida (2003) also find that the mobility of inventors is associated with interfirm knowledge flows regardless of geographic proximity. Corredoira & Rosenkopf (2010) find that a firm experiencing outbound mobility is more likely to cite the firm receiving the mobile employee, suggesting that it is not only the hiring firm that wins from inventor mobility. Song, Almeida and Wu (2003) study the patenting activities of engineers who moved from U.S. firms to non-U.S. firms finding evidence that domestic mobility and international mobility are similarly conducive to learning-by-hiring.

Large scale studies on the mobility of researchers between universities and firms as conduits of knowledge transfer are very rare. The problem is lack of good large databases on labour mobility of university trained scientists. In the US the regularly collected surveys on earned doctorates provide data on employment of PhDs (Sauermann & Roach (2013), which is followed in only a few European countries (eg Pellens & Veugelers (2013) on Belgian data). Similarly to the inter-firm mobility literature, the various applicant institutions can be traced for inventors through the standardized patent databases, providing a proxy for the mobility of university researchers to industry, at least those which are active in patenting (o.a. Breschi & Lissoni 2003). Tracing mobility from the university through exit information from university personnel databases is still in development[1]. Perhaps the most promising avenue to study (post-)graduate mobility is the use of linked employer-employee data (LEED). The Scandinavian countries have been the most open in providing this data for analysis. Kaiser, Kongsted and Rønde (2011) show that mobility of highly skilled workers increases the total innovative activity of both the new and the old employer in Denmark. In a study using the same Danish data, Ejsing et al. (2013) *concentrate on the mobility of university researchers and find that* firms' hirings of university researchers can provide important support for boundary-spanning search that leads to more firm-level innovation. This suggests that university-trained researchers will not only be important to contribute to the firms' own R&D activities, they are also important pathways for firms to better absorb external R&D. For instance, Lopez-Garcia and Montero (2012) show for Spanish firms that human capital positively affects the decision to innovate through its impact on firm's absorptive capacity.

[1] The US STARMETRICs partnership between US science agencies (like NIH and NSF) and universities to document the outcome of public investment in research at universities, has as a major component, the impact on the career and mobility of researchers (see www.starmetrics.nih.gov). A similar EU partnership is in development.

4. THE TECHNOLOGY TRANSFER ROLE OF UNIVERSITIES: IMPEDIMENTS AND LEVERS

While on average the evidence suggests a growing trend in -and a positive effect of- knowledge transfers from science to industry, there is nevertheless a strong suggestion of an inadequate scale and intensity of such transfers, with the link between science and innovations neither direct nor close. The highly uncertain and non-codifiable nature of scientific know-how results in high transaction costs and systemic failures in the market for this know-how, explaining the difficulty of organizing industry science links.

In Europe, the gap between high scientific performance on the one hand and industrial competitiveness on the other hand appears particularly wide. This gap is also known as the "European paradox" (EC (2002)). Low levels of Industry Science Links (further abbreviated as ISLs) can be attributed to a lack (1) in demand at the enterprise side, i.e. a specialization on innovation paths that do not require scientific knowledge or expertise, and/or a lack of (2) appropriate incentive structures and supportive institutional factors at the science side. A partners' lack of understanding of the other partner's culture and *conflicting objectives* among partners may further impede good industry science relations, notably the conflict of interest between the dissemination of new research findings versus the commercial exclusive appropriation of new knowledge (Siegel et al. 2003).

The next section will further look into the factors that might impede technology transfer on the science side.

4.1. INTELLECTUAL PROPERTY RIGHTS REGIME

A factor which receives quite some attention as conditioning feature for smooth industry science links is a clear *intellectual property rights* regime (Link, Scott & Siegel 2003). The Bayh-Dole act in the US shifted the ownership of publicly funded research from the state to the research sector. This is widely seen as a trigger, creating stronger incentives for universities to look for commercial applications of their research (Mowery & Sampat 2005). Most European countries have followed suit and implemented their versions of Bayh-Dole (Van Looy 2009). Countries also differ substantially on how the property rights are allocated within universities: i.e. to the individual researcher (professor's privilege) or the institution (Van Looy 2009).

4.2. INCENTIVE SCHEMES

A major issue that universities are facing is whether researchers have sufficient *incentives* to disclose their inventions and how to induce researchers' cooperation in further development following license agreements. Although the Bayh-Dole act stipulates that scientists must file an invention disclosure, this rule is rarely enforced. Instead, the university needs to have proper incentive schemes in place to induce disclosure, specifying a fair share for the inventors in royaltees or equity. This is studied in Macho-Stadler et al. (1996), Jensen & Thursby (2001), Thursby, Jensen & Thursby (2003). Lach & Schankerman (2008) provide strong empirical evidence in support for the importance of inventor royalty sharing rules for university performance in terms of inventions and licence income. Analysing panel data on US universities they find that private universities with higher inventor shares have higher license incomes, as they have more inventions disclosed that can be licensed.

Beyond incentive structures involving pecuniary rewards, the non-pecuniary reward structure in place at universities matters. Tenure and promotion criteria favoring teaching, research rather than tech transfer performance will have an impact on the efforts devoted by faculty in any of these activities.

Also influencing the incentives for academic researcher to patent or not their inventions, is the legal framework for patenting, most notably the grace period for patenting after publication of the results. The shorter this grace period, the more likely that researchers motivated to publish will refrain from patenting. The grace period can therefore be seen as an instrument to help ease the tension between publishing and patenting at universities. To this end, the absence of a serious grace period in Europe, compared to other countries like the US or Japan, may hamper the appetite for patenting by academic inventors in Europe (eg ScienceBusiness 2013)).

4.3. DEDICATED ORGANIZATIONAL STRUCTURES: TECHNOLOGY TRANSFER OFFICES

Bercovitz et al (2001) on a sample of US universities provide evidence of the importance of the *organisational structure* within the university for linking up with industry. Universities with a high record in ISLs most often apply a decentralised model of technology transfer, i.e. the responsibilities for transfer activities are located close to research groups and individuals. Associated with a decentralised model is the provision of adequate administrative support which allows the researcher to concentrate on R&D efforts and knowledge exchange, leaving most administrative activities associated with transfer activities (such as legal agreements, financial issues etc.) at specialized organisational units. Furthermore, specialized support should also include the field of commercialisation of R&D results via patenting and licensing where specific legal and marketing know how is needed.

Within a decentralized model of technology transfer, creating a specialized and decentralized *technology transfer office* (TTO) within the university is instrumental to secure a sufficient level of autonomy for developing relations with industry. This provides a better "buffer" against possible conflicts of interest between the commercialization and the research and teaching activities. A dedicated transfer unit also allows for specialization in supporting services, most notably management of intellectual property and business development. A higher degree of financial and managerial independence further facilitates relations with third parties, such as venture capitalists, investment bankers and patent attorneys (De Backere & Veugelers (2005)).

In addition, TTOs may have an incentive to invest in expertise to locate new inventions and sort profitable from unprofitable ones. The sunk costs to acquire this expertise can be overcome if the size of the invention pool is large enough. Using an asymmetric information framework, where firms have incomplete information on the quality of inventions, Macho et al (2007) develop a reputation argument for the TTO. The TTO being able to pool innovations across research labs, will have an incentive to "shelve" some of the projects, thus raising the buyer's beliefs on expected quality, which results in less but more valuable innovations being sold at higher prices. However, the TTO will not have enough incentives to maintain a reputation when the stream of innovations of each research lab is too small and/or the university has just a few of them. Their reputation model for a TTO is thus able to explain the importance of a critical size for the TTO in order to be successful as well as the stylized fact that TTOs may lead to less licensing agreements, but higher income from innovation transfers (Siegel et al. 2003)).

Against the benefits which a TTO can deliver, there is however the issue of scale as smaller universities often lack the resources and technical skills to effectively support such organizational arrangements and investments. In fact, universities need to produce a large number of patentable inventions every year in order to break even on their TTO activities (Scherer and Harhoff, 2000). At the same time, a separate TTO unit needs to be able to maintain close enough relationships with the researchers in the different departments. A dedicated Technology Transfer Office needs to assure appropriate incentive mechanisms both for its own TTO personnel and with its researchers overcoming moral hazard problems to ensure generation and disclosure of research projects (see eg Jensen et al (2003)).

The empirical research on best practices at TTOs underscores the importance of identifying the interests and incentives of those who manage the technology transfer process (see Box on best practices from LERU). These studies also highlight the importance of human capital (e.g., staffing of TTOs, "star scientists" and entrepreneurial teams) and the university culture (e.g., the role of department chairs, and entrepreneurs who are employed at these institutions) and group norms (see Siegel et al. 2007).

Box 2: Some best practices on technology transfer from LERU

A survey of 12 European Universities, all members of the League of European Research intensive Universities (LERU), shows high levels of similarity in the approach adopted towards managing ISLs as well as the incentives provided at the respective institutions. It is obvious that the level of maturity with TTO structures and ISLs can differ amongst the institutions surveyed. However, the basic approaches and tenets are quite similar. More specifically:

– The universities surveyed consider the exploitation of research activities as an explicit mission of their institution.

– All universities surveyed recognize the need to support a mix of ISL activities ISLs, IP management and spin-off creation generate important spillovers amongst them. Every university surveyed combines the three activities in its TTO structure.

– Each university also recognizes the need to decentralize its TTO structure, with a lot of frequent interactions with the research groups and the TTO on what to exploit under what conditions using which mechanisms.

– Each university has a well-established incentive policy towards its researchers. The incentives, financial and administrative, occur both at the level of the individual researchers involved in exploitation of research as well as at the level of the research groups involved.

Source: Debackere & Veugelers (2005).

5. EVIDENCE ON TECHNOLOGY TRANSFER BY UNIVERSITIES

As already indicated, there are multiple channels through which university research may contribute to innovation. Some of these channels are more amenable to quantitative assessment of impact, others far less so, although these may be at least as important, if not more so.

This section tries to provide an overview of the quantitative importance of the various channels. With its focus on providing empirical evidence, it obviously entails a bias in favor of the channels which can be more easily measured. Other helpful reviews of this vast literature are Siegel et al. (2007); Rothaermel et al. (2007); Astebro & Bazzanini (2011).

5.1. SOURCES OF TRANSFER REVENUE FOR UNIVERSITIES

Within the desert-like landscape of evidence on technology transfer activities in Europe, the HEFCE-BCIS data for the UK stand out, permitting a wider and regular evidence on revenue associated with technology transfer. Real income from external sources for UK universities more than tripled between 2001 and 2010 (HEFCE, 2011b). These increasing numbers suggest that external users of university links have exhibited an increased willingness to pay for access to university services, inputs and facilities.

For UK universities, the largest component of transfer related external income was contract research, which accounted for about one third of the revenue. The next most important component was collaborative research. Continuing Professional Development and Continuing Education is the next most important source of external income, its share rising from 15% to 18%. Regeneration and Development programmes, which are closely linked to regional and location specific links, have been declining in recent years from 11% to 6%. This source of income has been affected by the reorganisation of regional support policy in the UK and by the downward trend in EU and UK support for regional development in the UK. Use of facilities and equipment has remained at around 4% of income. Intellectual property was the least important source of income accounted for between 2% and 4% of income. With regard to spinoffs, the impacts are extremely skewed towards just a handful of highly successful cases. The research investment per university spin-off in the UK appears to be less than half the equivalent figure in the US.

The HEFCE data for the UK are very consistent with survey evidence on UK academics (Cosh et al (2006)). This evidence reveals that, while their level of engagement with industry has been rising as the barriers to engagement have declined, UK academics are involved in a variety of industry links, engaging in at least one or two types of links with industry, Moreover, while only a small proportion of academics have been involved in 'narrow' forms of commercialisation such as patenting, licensing or forming a spin-out company, far more have engaged in 'softer' people-based forms of interactions such as consultancy, attending meetings, giving talks, and helping with problem-solving (cf infra).

5.2. UNIVERSITY PATENTING

The trend of a more prominent role of universities in technology development and the rise of the entrepreneurial university, as discussed supra, is perhaps most notably associated with growing number of patents generated by universities. Table 1 shows the growing share of universities as assignees in EPO patent application[2]. Over the last three decades, the university share in patenting activity, although rather modest, has almost quadrupled from less than 1% in the eighties, over 2% in the nineties to over 3% by 2007 (Veugelers et al , 2012). Although the share is small, the fact that it is increasing reflects that university patent applications have risen faster than overall patenting activity, which has already by itself risen substantially over the considered period.

[2] In this exercise, patents are allocated to the university sector when a university institute is among the assignees. This is an underestimation as this does not include the patents where university faculty are (co-)inventors on patents where the university institution is not the applicant. Research (Lissoni et al (2008) has indicated that this can be a significant share of patents, particularly in some countries like Italy. Systematically tracing these patents would however require a mapping of all individual inventors to their institute of employment, which is not feasible.

Table I. Trends in university participation in technology development

(university assignees, EPO).

Sector	1980 – 1985	1986 - 1990	1991 – 1995	1996 - 2000	2001 - 2007
Company	84,90%	87,04%	88,55%	88,42%	89,02%
Government / non-profit	2,41%	2,36%	1,98%	2,09%	2,29%
Hospital	0,07%	0,15%	0,19%	0,22%	0,19%
Individual person	11,84%	9,30%	7,70%	7,00%	5,84%
University	0,79%	1,16%	1,57%	2,28%	2,66%
	100,00%	100,00%	100,00%	100,00%	100,00%

Source: Veugelers, Callaert, Van Looy (2012)

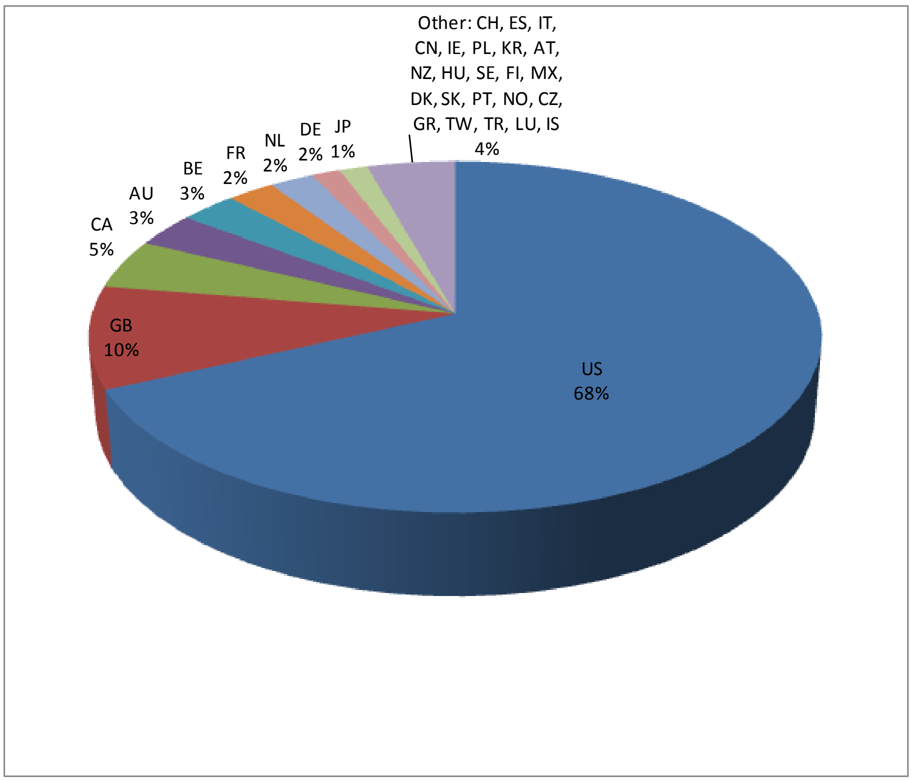
University patenting is not only a small, albeit growing, phenomenon in the patent landscape, it is also a skewed phenomenon. Only a few countries and a few institutes account for the bulk of university patenting. Figure 1 shows that 68% of all university patents are held by the United States[3]. Also only a limited number of institutes account for the bulk of university patenting. The worldwide top 25 players in university patenting, although they represent only 2.6% of all patenting universities, hold almost 40% of all university patents. US universities figure prominently in this top (22 institutes, with the University of California, coming first, followed by MIT).

European countries (EU-15) take a much lower share in university patenting: 21%. Within Europe, the UK is the largest player, and number 2 in the world. The low share of EU-15 is due to the fact that many of its major patenting countries are only to a very limited extent active in university patenting: most notably Germany, France, the Netherlands and Italy as well as Scandinavian countries. For a number of these countries, this is a consequence of the regulations on intellectual ownership within academia. Several European countries have only recently (after 2000) abandoned the 'professor's privilege' rule in favour of 'Bayh-Dole' oriented regulations (e.g. Germany and Denmark), while Italy has introduced the professor's privilege (see Van Looy, 2009). In addition, in some countries – notably Germany, France and Italy – a

[3] Note that the figures concern EPO patents, so this prevalence holds in spite of a potential home bias for European countries.

considerable part of publicly funded research is conducted at Public Research Organisations, like CNRS, CNR, Fraunhofer. Consecutive technology development activities undertaken by these PRO's are not included in the data analysed here, where the focus is on universities exclusively.

Figure 1: University patenting by country (EPO, application years 1980-2000).



Source: Veugelers, Callaert, Van Looy (2012)

Academic patents often represent early stage technology development, where the potential use is still unclear or uncertain and many academic patents are likely to not deliver successful innovations (e.g. Jensen & Thursby, 2001). Furthermore, Thursby & Thursby (2002) argue and illustrate that much of the growth in US academic patenting is due to marginal and average performing universities catching up in quantity of patenting to the most prolific universities. Hence, with a substantial tail of zero or low impact patents, it becomes more relevant to look at the quality of academic patenting rather than whether and how often universities apply for patents. What critically matters is whether university technology creation will be relevant for subsequent technology development. As most of the patent applications never get used, it is more important to look at those university patents that are actually being used for further development.

One way of assessing the impact or use of university patents is to consider whether they are licensed or not (e.g. Link, Scott & Siegel, 2002). Such an approach however would require comprehensive data on licensing activities covering different countries and technology fields that are not yet available. The following table is constructed on the basis of AUTM (www.AUTM.net) and ASTP survey data, which are the best possible data sources on this, but for the moment still, particularly for Europe, not comprehensive.

Table 2: Licensed university patents: Europe vs US

	US universities	European universities
Patents granted as % of patent applications	0.40	0.35
Licenses executed as % of patent applications°	0.87	0.43

° Licenses executed are for the same year as the patent applications and patents granted. Licenses can however also be executed for previously applied and/or granted patents. The reported number therefore does not reflect the share of patents which are licensed in a given year.

Source: Own calculations on the basis of Arundel & Bordoy (2006), on the basis of ASTP and AUTM surveys.

Table 2 suggests that US universities are more likely to get their patents granted when applying, compared to European universities. US universities also have more licenses executed as compared to their European universities.

License income is even more skewed in a few blockbuster cases than university patenting. Thursby and Thursby (2007) report that only 0.48 percent of all active licenses generated licensing income of $1 million or more. Scherer and Harhoff (2000) compute that the top ten percent of all Harvard patents provided 84 percent of the gross economic value of Harvard's patent portfolio. For the UK about 80% of the licensing returns accounted for by 20% of the cases. The top 2 cases (representing 3% of the sample) appear to have accounted for more than one third of the overall total (Russell Group, 2010). There are spectacular returns as demonstrated by Stanford University and University of California combined licensing revenues from the Cohen-Boyer patent on recombinant DNA. But these are rare events.

Licensing is a rather restrictive operationalisation of valorization, as the use of the university invention requires a monetary transfer to be recorded. An alternative approach used in Veugelers et al (2012) is to use patent citations. Patent citations reveal to what extent future technology development efforts are related to the knowledge reflected in the source document as prior art for their technology developments (Jaffe et al., 1993). Veugelers et al (2012) use citations from corporate patents to university patents to trace the "use" of academic inventions as cited documents by further corporate inventions citing the academic invention as prior art[4].

Table 3: Corporate citations to university patents by country.

Country	Country share in university patents	Country share in all corporate citations received by university patents	% university owned patents that are cited by company patents	average number of corporate citations to univ patents
US	69.8	66.8	14%	6,03
UK	9.7	6.5	15%	3,96
BE	2.9	6.2	36%	5,17
FR	2.4	2.3	28%	3,03
NL	2.2	3.0	28%	4,26
DE	1.5	1.4	22%	3,89
JP	1.4	3.8	49%	4,77
CH	0.95	1.1	23%	4,29
ES	0.66	0.9	40%	2,98
IT	0.53	0.5	21%	3,90
EU-15 (avg)	21.65	22.8	27,8%	3,74

Source: Veugelers, Callaert, Van Looy (2012)

Table 3 shows the citation-based statistics for a selection of countries. The table reveals different profiles for each of these world regions. In terms of numbers of academic patents, the US is

[4] The analysis uses EPO application data for the years 1980-2000, which allows a citation window of 10 years (until 2010). Citations are from all patent systems (USPTO, EPO…). For more information on the database and further analysis, see Veugelers et al (2012)).

clearly dominant, as already shown in Figure 1, leaving the EU-15 far behind. However, only a limited number of US academic patents are, in the end, cited by the corporate sector (14%). This citation rate is much higher for university patents from the EU-15 (28%) and particularly for Japan (48%). Hence, these countries have fewer but more frequently cited university patents by the corporate sector. However, when looking at the average number of citations received, conditional on being cited, the US again takes a strong lead over the EU-15 and Japan, with their university patents having a higher impact on average.

These results suggest that, in terms of profiles, the US model of university technology creation seems to be one of experimentation on a large scale. They generate a large volume of university patents, from which only a minor portion end up being 'used' in subsequent corporate technology creation. This large volume allows simultaneously for a more fertile ground for university patents to bloom into 'hits', or highly cited patents, at least for a few. This experimentation process is especially typical of the Biotech (Pharmaceutical) field. The profile of Europe suggests more mediocracy: universities are much less active in generating patents, only bringing out those ideas that have a relatively high probability of becoming 'used'. However, with less experimentation going on, they are less likely to result in 'high impact'. Heterogeneity in Europe, in terms of both institutional texture as well as legislative framework conditions pertaining to the ownership of publicly funded research, is partly responsible for the observed country differences (Veugelers et al (2012))[5].

5.3. UNIVERSITY SPIN-OFFS

While basic research results can be channeled to industry via collaborative research schemes or licensing arrangements of patented university inventions, **spinning off** is the entrepreneurial route to commercialise public research. The latter attracts a great deal of policy attention in many countries. Assessing the spin-off formation rate is often seen as a key indicator for the quality of ISLs.

[5] Within the EU-15, Belgium's university patents hold a top position in terms of corporate citations received. Not only do Belgian university patents have a higher probability of receiving citations by corporate patents, they also have the highest impact in Europe. The Belgian university patenting success story largely benefits from the presence of IMEC, an interuniversity centre for micro-electronics.

Contrary to university patents, which can be traced with internationally available data (cf OECD's Patstat), no such data exist for spin-offs that can be compared across countries and time. Empirical analysis of this phenomenon has to rely on selected surveys, most notably surveys from the US AUTM and their European counterparts, ASTP. With the caveat of difficult international comparisons and imperfect coverage, particularly in Europe, these data confirm the US superiority in generating university spin-offs, even when correcting for the differences in research expenditures available to US universities compared to Europe.

Table 4: University spin-offs: Europe vs US

	US universities	European universities	Ratio
Spin-offs per million PPP $ research expenditures	0.028	0.011	2.55

Source: Arundel & Bordoy (2006), on the basis of ASTP and AUTM surveys.

University start-up activity has started to attract considerable attention in the academic literature, particularly in the US. DiGregorio and Shane (2003) directly assess the determinants of startup formation, using AUTM data from 101 universities and 530 startups. They find that the two key determinants of the number of start-ups by universities are (i) the research quality of its faculty and (ii) proper incentive schemes, in casu the ability of the university and inventor(s) to assume equity in a start-up, in lieu of licensing royalty fees. O'Shea, Allen, and Arnaud (2005) confirm these findings but find that also a university's previous success in technology transfer is a key explanatory factor of start-up formation, as well as the extent of federal science and engineering funding.

Lockett, Wright and Franklin (2003) find that universities that generate the most startups have clear, well-defined strategies regarding the formation and management of spinoffs. The more successful universities have greater expertise and vast social networks that help them support more startups. Lockett and Wright (2005) find a positive correlation between startup formation, the business development capabilities of TTOs, and the extent to which its royalty distribution formula favors faculty members.

Although significant research efforts have been devoted to try to measure and analyse the formation of university spin-offs, far fewer studies have looked at the growth of university spin-offs. For instance, Klepper and Sleeper (2000) show that in the US laser industry, spin-offs have outperformed other start-ups. While the survival of university start-ups is higher than for the general start-up, the survival rate of spin-offs from leading universities is even higher. Shane (2004) estimates that 80 percent of MIT spin-offs started between 1980 and 1996 survived 1997. Of the 153 spin-offs created at ETH Zurich, Switzerland, in the period 98-08, 90% survived beyond 5 years.

University-based start-ups also seem to create much more jobs than the typical start-up. AUTM data show 83 employees per spin-off during the period 1980 to 1999 while the number of employees for the typical start-up with employees is 3.8 (Shane, 2008). Other countries also show high rates of employment from spin-offs. One study for the UK found an average of 44 jobs (Charles and Conway, 2000). Blair and Hitchens (1998) estimated that the spin-offs in Northern Ireland and the U.K. employed three times the fraction of university graduates than regular firms.

5.4. STUDENT SPIN-OFFS

The empirical evidence on technology transfer almost exclusively covers patents and start-ups by faculty and staff. Existing empirical work (in particular all the work based on AUTM data) does not cover firms started by students because these are typically not using IP based on university funding. There are no general data on the rate by which students start up new businesses upon graduation, but there are several university-specific alumni surveys. Astebro & Bazzazian (2011) claim that student spin-offs are probably order of magnitudes larger than faculty spin-offs, at least in terms of number of firms. Their calculations for the MIT case, admittedly perhaps one of the best cases for student spin-offs, indicate a student-to-faculty spin-off ratio from 12:1 to up to 48:1. In any case, student spin-offs deserve much more attention and empirical evidence and analysis than it currently receives.

5.5. *BEYOND THE TECHNOLOGY TRANSFER MODEL*

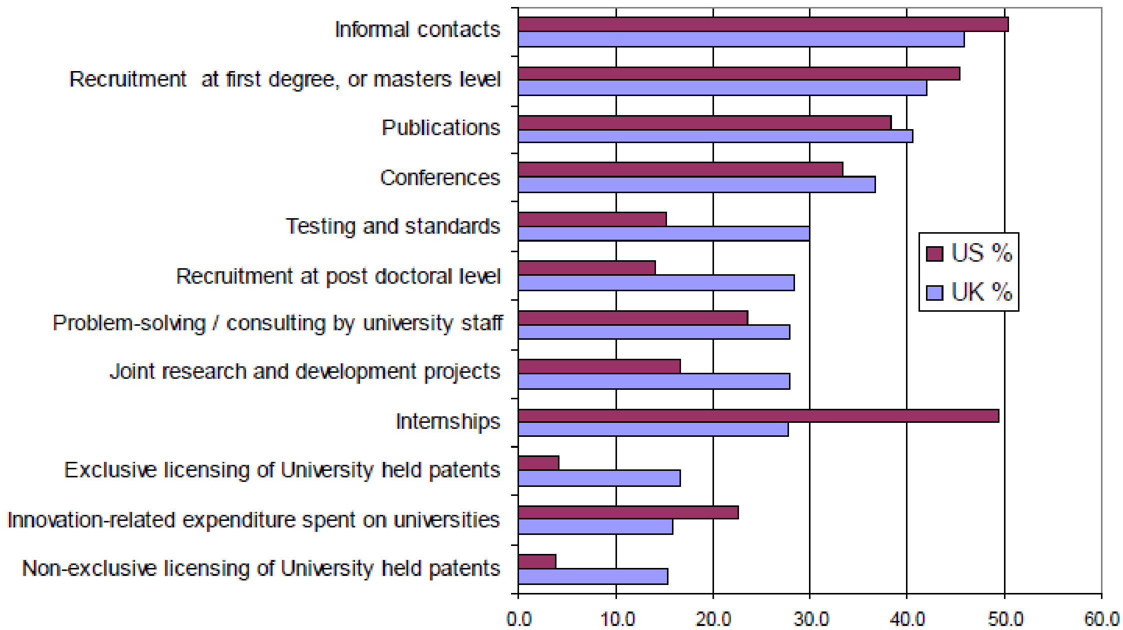
The overall economic significance of the technology transfer model, with its focus on patenting and spin-offs, has often been exaggerated. The best-known success stories are atypical. New business formation around university science and technology is a very small fraction – probably no more than 2-3% – of the total rate of new business starts, even in the U.S. The same is true of patenting. University patenting is only a minor contributor to the overall stock of patented knowledge, as Table 1 indicated. And for universities, there may be spectacular returns, like the licensing revenues for Stanford University and University of California on the Cohen-Boyer patent on recombinant DNE or Stanford's return on its 2% ownership of Google on its IPO. But the likelihood that this happens is extremely low. In fact, universities need a very large number of useable inventions every year in order for their TTOs to break even.

Patenting and licensing is only one of a number of pathways for the transfer of knowledge from universities to industry (Cohen, Nelson & Walsh (2002). Firms may alternatively exploit recent university research results published in the open literature; or they may use university scientists as consultants to apply well-established engineering or scientific knowledge to the development of a particular product; or they may collaborate with university scientists and engineers to apply new scientific knowledge developed by researchers at other universities; or, and perhaps most often, they may recruit the students of the leading university researcher in the field.

A UK-US survey asked the responding firms to indicate the types of university-industry interactions contributing to their innovation activities (Cosh et al (2006)). In both countries, informal contacts were the most important contribution, followed by recruitment at first degree or Masters level, publications and conferences. Patenting and licensing appear low down the list of business perceptions with regard to university interactions contributing to innovation.

Figure 2: Types of university-industry interactions contributing to Innovation

% of firms rating mode



Source: Cosh et al (2006)

This confirms that the best form of technology transfer, at least the most often used, may not be patenting, licensing and spin-offs but the moving van that transports the graduate or PhD from his or her university to a new job in industry. This implies that the university's most important contribution would run through its first mission of education and training.

Unfortunately this pathway remains relatively unexplored in academic work, often hampered by data availability. Rosenberg & Nelson (1994) when they describe the strong points of the US National Innovation System emphasize the critical role of American universities, noting particularly their role of training. They note that in each one of the new engineering disciplines, as they emerged, American universities were not only responsible for a great deal of generic and applied research of immediate practical value to industry but were very quick to start new courses and train postgraduates. After showing that this was the case in electrical engineering, in chemical engineering and aeronautical engineering, they show that it was also true of computer science and of course of biotechnology. ''If we review the history of the development of a number of important engineering disciplines, it seems apparent that engineering education in the US has consistently attempted to provide reference points for inquiry into the details of very practical problems. At the same time, university research has been instrumental in providing an appropriate intellectual framework for training efficient professional decision-makers'' (Rosenberg and Nelson, 1994, p. 333).

6. UNIVERSITIES AS ECONOMIC SECTOR: DIRECT AND INDIRECT EFFECTS ON JOBS AND GDP

Universities can also be considered as independent business entities and the economic activity generated by institutional expenditures can be substantial. An important element of the role that HEIs play in the economy is related to how many staff they employ. They tend to be labour intensive enterprises and can be very large employers. Indeed they are frequently among the largest employers in their regions. HEIs do not only employ academics but provide jobs for a very wide range of staff. And what is more, they generate indirect employment in other sectors in the local economy.

Case studies on individual institutes and their impact on their local economy are plentiful (see eg DIWecon (2008) on the impact of TU Berlin on the Berlin economy). These case studies are mostly for a "local" audience in the local language and using ad hoc methodologies to assess indirect impact, typically missing proper "counterfactuals" (Goldstein 2009). A macro-economic assessment of the importance of universities as economic sector for economies is rarely done. We report in this section studies for the UK and Spain.

The UK provides a recurring analysis of the impact of universities (UniversitiesUK 2006). Not surprisingly, for the UK this impact can be substantial. The extensive scale of higher education institutional activity across the UK means that its impact can have an important macroeconomic significance. The UK results may therefore not be very representative for other countries with a smaller and less performing university sector.

The results from the last UK exercise (UniversitiesUK 2006) shows the following results:

<u>Direct effects:</u>

- In 2003-2004, the total revenue earned by UK HEIs amounted to £16.87 billion. In terms of sectoral gross output this was greater than the UK pharmaceutical industry and only slightly smaller than UK legal activities and auxiliary financial services
- The revenues generated from abroad by HEI (institutional *gross export earnings)* amounted to nearly £2 billion representing nearly 12% of all HEI income.

- HEIs *directly* employed over 330,000 people, which equated to approximately 280,000 full time equivalent (FTE) jobs. This was equivalent to 1.2% of total UK employment. Jobs are across a number of occupations: 44% academic, while 56% are other support staff

<u>Indirect effects:</u>

- The ratio of total output to direct output is defined as the ***sectoral gross output*** multiplier, with a calculated value for the HEIs of **2.52.** Therefore, for every £1 million of HEI direct output a further £1.52 million was generated in other sectors of the economy. This meant that an additional £25.6 billion of output was generated outside the HEIs as a result of their expenditure.
- For every 100 full time jobs within the HEIs themselves, a further 99 FTE jobs were generated through knock – on effects. Over 276,400 jobs in other sectors of the economy were dependent on the HEIs.
- Beyond the international revenue earned directly by the HEIs, there is another £1.6 billion of additional personal expenditure of international students and visitors, leaving a total of gross export earnings for the **HEI sector** in 2003-2004 estimated to be over £3.6 billion.
- In 2003-2004 the HE sector spent some £15.4 billion on goods and services produced in the UK.

Through both direct and secondary or multiplier effects the HEI in the UK **generated** over £45 billion of output and over 581,000 full time equivalent jobs throughout the UK economy in 2003-2004. The total employment generated was equivalent to around 2.5% of the workforce in employment.

Several studies compute the economic impact of different universities in Spain. Duch, García and Parellada (2008) provide such estimates for the whole Spanish university system for the period 1998-2004. For 2004, they report 139.822 jobs directly related to the university system (0.7% of employment that year). When accounting also for jobs indirectly related to the university system, the figure goes up to 254.894 (1.5% of total employment in Spain). The direct contribution to Gross Added Value is 4.767 million (0.5% of GDP, arriving to 1% of GDP when accounting for indirectly related Gross Added Value). Fundación CYD in its 2004 Report provides an estimate of the *sectoral gross output* multiplier of 1,304.

7. THE CONTRIBUTION OF UNIVERSITIES TO LOCAL DEVELOPMENT

Governments have become increasingly active in pressing the public universities within their jurisdictions to contribute to local economic development. Beyond the direct impact from universities, their presence may also attract other key economic resources to the region, including firms and workers, educated or not, who may want to locate close by, as well as financiers, entrepreneurs and others seeking to exploit new business opportunities emanating from the campus.

Several studies have empirically confirmed the role of human capital for regional development. Gennaioli et al. (2011) investigate the determinants of regional development using a database of 1569 sub-national regions from 110 countries and find that human capital (measured using education) emerges as the most consistently important determinant of both regional income and productivity. Other studies look more specifically at the role of knowledge centers like universities in regional development (Anselin et al., 1997; Varga, 1998; 2000; Blind & Grupp, 1999; Acs et al., 2002; Fischer & Varga, 2003; Drucker and Goldstein (2007)). The development of such university based regional centers require a long term perspective: the slow emergence of high tech regions such as Silicon Valley, Cambridge and Sophia Antipolis show that economic effects are the result of a decades-long development process (Saxenian, 1994). They also show a multitude of pathways for local impact.

7.1. THE MANY PATHWAYS TO LOCAL IMPACT

Many material interdependencies exist between universities and their regions.

There is first the direct impact from the university on the region. Being labour intensive, universities are large employers, often the largest in their region (see section 6). They attract considerable numbers of students, business visitors, tourists and project funding to regions (see section 6).

But most often considered is the indirect impact which universities can have on their region, particularly on the region's innovation capacity. The notion that universities can contribute to regional innovation builds upon two key ideas: firstly that universities increase knowledge production through the provision of new workers (first mission) and scientific results (second mission) that can be turned into patents, products and services and secondly that the existence of universities in regions can lead to university–industry knowledge transfer and exchange (third mission). In this perspective, universities will contribute to building innovative regional economies though their three missions:

- providing excellence in education, leading to students who will stay in the region and contribute to its growth
- providing excellence in research that will be the sowbeds for new ideas, products and services in areas that underpin the region's economic base
- providing excellence in transfer and collaboration that will support public and private actors in the region.

There also exists a series of immaterial interdependencies between universities and regions. Universities are powerful symbols of learning and expertise. As such, the presence of established seats of higher education or world-famous research institutes can be important to regional branding. In the case of the world's older universities there is often an inseparable relationship between the university and the surrounding region or city's identity/image: e.g. Bologna, Heidelberg, Uppsala, Leuven, Oxford and Cambridge. Related to this is the idea that a region with a reputation for world-class research and education can have reputational halo effects to the wider regional economy.

7.2. The Regional Technology Transfer Model: Licensing and Spin-offs

At present the major focus in the contribution of universities to regional development is on technology transfer, more particularly patenting, licensing and spin-offs.

Universities are encouraged to transfer their laboratory discoveries by patenting and licensing intellectual property to local firms. AUTM reported in 1999 that 82 percent of firms from university licenses operated in the state where the university was located. By 2007 this number had dropped but still stood at 72 percent (Astebro & Bazzazian (2011).

Also university spin-offs have a strong Alma-Mater home bias. Academic entrepreneurship or spin-offs are a source of new firms and jobs and can be a significant revenue source for regions. Spin-offs from university or publicly funded research institutes can be important both as new material forces in the region and also as vehicles for regional technology transfer (Lindholm-Dahlstrand, 1997; Varga, 1998; Shane, 2004, Heblich & Slavtchev, 2013).

But universities do not only have an impact on new firm creation through their own spin-offs, they also correlate with other start-ups. Research has shown that geographical proximity to universities is positively correlated with regional startup rates in high-tech industries (e.g. Audretsch and Lehmann, 2005; Rothaermel and Ku, 2008).

Particularly student spin-offs are very likely to locate close to their Alma Mater. Using Swedish matched employer-employee records Baltzopoulus and Broström, (2009) are able to statistically estimate the effect of studying at a particular university on the probability that a student locates his/her startup in the region of the university as opposed to another region. Seventy-one percent of the entrepreneurs graduating from university start their business in the region where they were born. If the university was in the same region as they were born this probability increases to 87 percent. Among those who moved to study at a university in another region, 51 percent start up the business in the same region as the university. The university thus serves as a strong magnet to start-ups by alumni and breaks the otherwise very strong "home bias" that entrepreneurs have. Peer effects, local clusters and ties to professors seem to be behind the proximity to one's Alma Mater.

7.3. REGIONAL SPILLOVERS, CLUSTERS AND SCIENCE PARKS

Regional spillovers

Academic articles show the importance of proximity to the transfer/spillover of knowledge from universities to established firms' labs (e.g. Acs et al. 2002; Jaffe et al 1993; Mansfield and Lee, 1996; Audretsch & Stephan, 1996, Furman and MacGarvie, 2007). Most of these studies use citations to academic patents and/or publications to measure such spillovers.

Comparing across countries the citations from corporate patents to university patents, Veugelers et al (2012) confirm that such citation flows are indeed to a large extent localised (see table 5). Within-country links between the cited university patent and the citing corporate patents are overrepresented. This confirms that proximity matters for tighter links between creation and use of academic patents. At the same time, it can be noted that these localized patterns are mainly observed for European and Asian countries. US universities are always (for all citing countries) by far the largest recipient of corporate citations. Nevertheless, also for US corporations, it appears to be easier to link to US academic patents, compared to non-US corporations.

Table 5: Cross-country links between corporate citing patents and university cited patents.

	BE	DE	FR	IT	JP	NL	UK	US
BE	4.99	0.00	0.90	0.00	2.51	0.71	0.80	0.51
DE	1.22	2.69	1.35	3.51	0.82	0.84	1.11	0.86
FR	1.05	0.98	5.58	1.81	0.92	0.30	0.63	0.87
IT	1.37	0.00	0.64	2.03	1.73	0.84	1.00	0.95
JP	0.82	1.06	0.84	0.33	2.63	0.62	1.17	0.98
NL	1.17	4.26	0.82	3.25	1.28	4.65	0.96	0.74
UK	0.94	1.05	0.73	0.82	0.62	1.12	1.87	0.97
US	0.87	0.57	0.59	0.55	0.71	0.83	0.78	1.12

Source: Veugelers, Callaert, Van Looy (2012)

Note : The cell values represent relative intensities of citation linkages between the citing countries (rows) and the cited countries (columns), with grey cells indicating within-country citation flows. The following formula was used to calculate these relative intensities: citations of corporate citing country i to academic cited country j as a share of total citations of corporate citing country i divided by citations to corporate cited country j as a share of total corporate citations; A value higher than 1 represents a link between corporate citing country and university cited country which is overrepresented.

Spillovers are not only less likely to cross national borders, even within countries they tend to be localized. A recent study for the US by Belezon & Schankerman (2010) for example, using data on citations to university patents and scientific publications, show that knowledge flows from patents are localized in two respects: they decline sharply with distance up to about 100 miles, and they are strongly constrained by state borders, controlling for distance. For citations to scientific papers they find similar local effects, but no state border effect, controlling for distance.

This proximity effect found in patent citations analysis is confirmed in survey evidence. For example, Mansfield and Lee (1996) found that US firms prefer to work with local universities (within 100 miles of the corporate lab) and that firms support local applied research of less distinguished faculties nearly as much as faculty in top schools, though basic research supported by firms takes place mostly at top schools.

What are the environmental conditions that need to be in place for higher regional spillovers to prevail? Zucker and Darby (2001), studying data on the outcomes of collaborations between "star" university scientists and biotechnology firms find no geographically localized knowledge spillovers resulting from university technology transfer in Japan, in contrast to the U.S., where they found that such effects were strong. The authors attribute this to institutional difference between Japan and the U.S in university technology transfer. In the U.S., academic scientists typically work with firm scientists at the firm's laboratories. In Japan, firm scientists typically work in the academic scientist's laboratory.

Important to note is that the regional impact of universities does not need to be considered as following from an exclusive orientation of the university on the region. In fact, universities that are primarily extra-locally oriented may often play an important role in a region's economic life. Belenzon and Schankerman, (2009) show that public universities with strong local development objectives generate about 28% more licenses, but about 30% less income per license. These universities are further more likely to generate proportionally more in-state start-up companies while the total number of spin-offs is not affected. Hence, forcing an exclusive regional focus on universities may not be the best for regional development and can even be counterproductive.

Science parks and incubators

The proximity for transfer/spillovers of knowledge from universities to firms motivated the construction of science parks. Science parks started to be built in the 1950s in the U.S. (e.g. Stanford Research Park and the Research Triangle Park in North Carolina) and in the late 1960s in Europe, eg Sophia Antipolis in Nice in 1969. Their numbers grew rapidly in the 1980s and 1990s.

Locating on science parks provides firms closer access to university research in more informal ways. It may facilitate the recruiting of university (post-)graduates. Agglomerating firms in a park/building may furthermore lead to positive spillovers between participating firms.

For university spin-offs, a science park or business incubator near the university provides easy access to business resources while allowing the researcher to still be in close contact with his/her lab/university position.

The empirical literature that evaluates the role of science parks and incubators is still in its infancy. A major issue is in this literature is to properly account for the selection of firms into parks. As firms self-select to join science parks and incubators, models assessing the effect from locating in science parks must account for the quality of firms that select into science parks. Siegel, Westhead and Wright (2003), reviewing this literature find that most research on science parks fails to shows a significant impact on firm performance compared to firms not located in science parks.

Regional clusters

A related literature on local economic effects is that on "clusters." A regional technology cluster is defined by Porter (1998) as a "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities". Most of the existing theories of clusters of innovative activity focus on agglomeration economics and externalities (e.g. Audretsch and Feldman 1996; Saxenian, 1994). Within this literature one can look at whether and how universities support the formation of such clusters, with popular examples such as MIT and Stanford in mind.

Ellison & Glaeser (1999) show that clusters will be particularly successful in terms of knowledge spillovers when research institutes, universities and innovative companies are geographically concentrated. Also Van Looy, Debackere & Andries (2003), using evidence from various innovative regions around the world, examine the critical ingredients that can lead to regional innovation and economic success. These critical ingredients consist of a balanced mix based on the presence of research institutes, a texture of endogenous knowledge–intensive start–ups coupled to larger R&D–intensive incumbents, all of them embedded in a professional environment that supports business advice and services.

Despite these positive priors for universities' critical contribution to regional innovation clusters, the academic literature assessing the effects of university participation in regional clusters is like the literature on science parks, particularly weak in testing for causation, correcting for selfselection effects (Breshnahan, & Gambardella 2001). Although the evidence clearly supports a positive correlation between universities and regional development, such correlation does not necessarily proof causation. Are the universities the causes of local development or it is simply that these universities are located in fertile grounds for development? This cannot be determined by cross-sectional analysis.

To examine more precisely the issue of causality, Sweden provides an interesting case as it undertook a spatial decentralization of its higher education system in 1987.[6] Andersson, Quigley, and Wilhelmsson (2004; 2009) use this exogenous shock to estimate the effect of increased university employment and student enrolment on local productivity growth and patenting. The authors find large increases in local productivity around the new universities and a greater impact on productivity growth than the old established universities.

Using the interaction of a national shock to the spread of innovation from universities - the Bayh-Dole Act of 1980 - with pre-determined variation both within a university in academic strengths and across universities in federal research funding, Hausman (2012) identifies the extent to which U.S. universities stimulate nearby economic activity. Using longitudinal establishment-level data from the Census, she finds that long-run employment and payroll per worker around universities rise particularly rapidly after Bayh-Dole in industries more closely related to local university innovative strengths. The impact of university innovation increases with geographic proximity to the university. Counties surrounding universities that received more pre-Bayh-Dole federal funding - particularly from the Department of Defense and the National Institutes of Health - experienced faster employment growth after the law.

Regional graduate mobility

Most of the analysis on regional effects from universities is focused on technology transfer from university research, i.e. focusing on the second and third mission of universities. But also the first mission of universities may lead to strong regional effects, as the regional bias in student spin-offs already indicates. Through their education of students, universities can have a very real effect on the local provision of skilled labour in new spin-offs firms, but also in established firms

[6] Eleven new universities were created and 14 colleges were upgraded in status to create a total of 36 universities.

recruiting graduates. Unfortunately, there is very little data and analysis on regional graduate mobility (cf supra). Although many university towns view retention of graduates as a problem, there is no doubt that some in-moving students will stay after graduation.

Andersson et al. (2004; 2009) provide evidence for positive effects of increased student enrolment and investments at universities in personnel on local labor productivity growth and patenting activity. This growth is much faster in "structurally weak" regions. However, the universities also generate huge externalities outside the region since many student leave the region to take up jobs elsewhere, particularly in the US where there is a more integrated labour market. For evidence on the US on graduate mobility, see for example Stephan, Sumell, Black and Adams (2004).

A final piece of evidence on regional spillovers from university education comes from estimates of the spillovers from college education on the wages in the local labour market. Moretti (2004) estimates spillovers from college education by comparing wages of otherwise similar individuals who work in cities with different shares of college graduates. The conclusion is that such externalities exist, and can be huge, particularly on the lesser educated: "a percentage point increase in the supply of college graduates raises high school drop-outs' wages by 1.9%, high school graduates' wages by 1.6%, and college graduates wages by 0.4%". A major problem with assessing such local externalities is to properly account for endogeneity issues implied by a spatial equilibrium. In fact, Lange and Topel (2005) question the validity of the econometric analysis of Moretti (2004) and conclude that there is no compelling evidence of positive externalities to human capital investments.

7.4. BEYOND THE REGIONAL TECHNOLOGY TRANSFER MODEL

For many regions, technology transfer through university spin-offs or access to academic patents will not be the most important contribution of universities to their development.

Analysis from the MIT coordinated Local Innovation Systems Projects, drawing on studies of innovation-enabled industrial change in twenty-two locations in six countries in the period 2002-2005, confirms that there are several other pathways for universities to contribute to local development beyond university patenting and university spinoffs (Lester 2005). In addition to their own discoveries, universities may also be important actors to help transform existing industries, - improving the abilities of the existing network of local firms to *take up* new knowledge, and to *apply* this knowledge productively; universities can help to attract new knowledge, and financial resources from elsewhere. They can help to adapt knowledge originating elsewhere to local conditions. They can help to integrate previously separate areas of technological activity. They can help to unlock and redirect knowledge that is already present in the region but not being put to productive use.

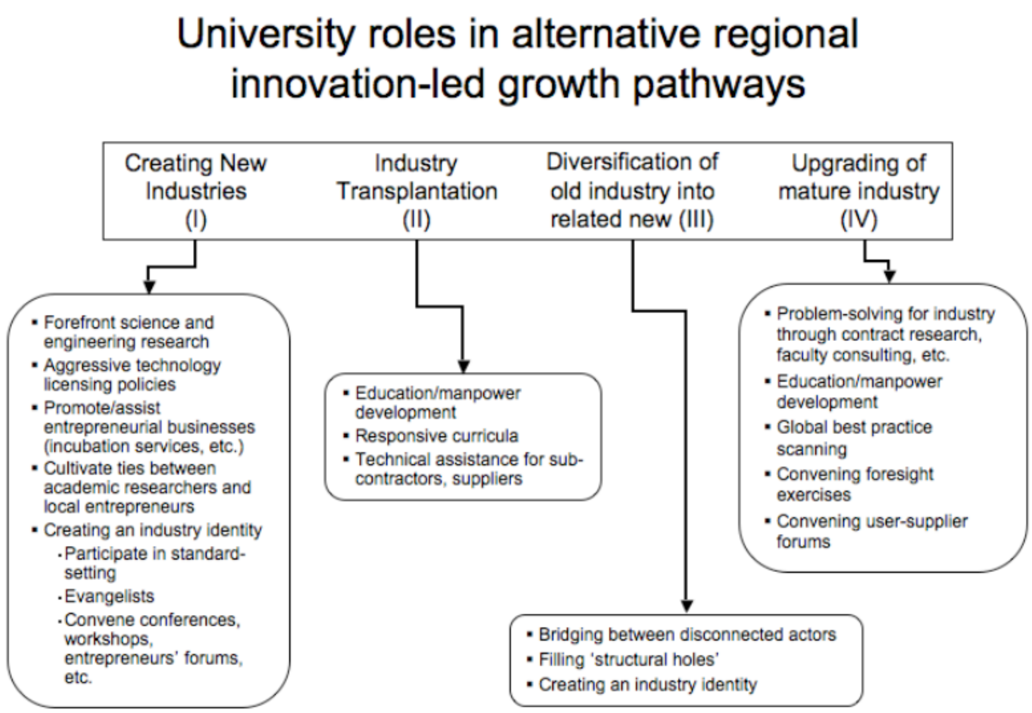


Figure 2: University roles in alternative innovation-led local/regional growth pathways

Source: Lester (2005)

In cases of new industry creation a local university or public research laboratory typically played the role of anchor institution, whereas in the case of industry upgrading the anchor institution was more likely to be a lead firm or a lead customer. In science-based industry formation the highest-impact educational outputs of local universities were Ph.D.-level scientists and engineers with an interest in entrepreneurial careers and some exposure to entrepreneurial business practices. For cases of upgrading, bachelors and masters-level engineering graduates equipped with knowledge of the industry's practices and problems obtained from classes, practical theses, and internships were of greatest value. For science-based industry creation, university technology transfer was proactive and oriented towards start-ups and small firms. For industry upgrading these arrangements were more likely to center on long-term relationships between the university and established firms. In some of the cases of new industry creation (though not all) a local university played a leading role. But none of the upgrading processes were university-led, although in some cases local universities played important supporting roles.

These findings cast further doubt on the utility of a one-size-fits-all approach to economic development that so many universities have been pursuing, with its focus on patenting, licensing, and startups. It calls for a broader view of the university's role in local economies – as creators, receptors, and interpreters of innovation and ideas; as sources of human capital; and as key components of social infrastructure and social capital.

8. POLICIES TO ENHANCE UNIVERSITIES' CONTRIBUTION TO INNOVATION

Since the eighties numerous countries have implemented or considered policies to strengthen "linkages" between universities (and public research organizations) and industry, in order to enhance the contributions of university-based research to innovation and economic performance (Cohen and Noll, 1994). Most of these policy initiatives share the premise that universities support innovation in industry primarily through the production by universities of "deliverables" for commercialization (e.g., patented discoveries), despite the modest support for the importance of this gateway in the research discussed above.

This section discusses a few of the most frequently used policy instruments for improving universities' contribution to (local) innovation and growth: IP ownership regulation (Bayh-Dole type of regulations), support for industry-science collaborative research and support for institutional tech transfer building (Technology Transfer Offices, Science Parks and Incubators). The current stage of research in this area is still far from being able to assess whether such policy interventions are indeed effective to stimulate the contribution of universities to innovation.

8.1. INTELLECTUAL PROPERTY RIGHTS; BAYH-DOLE

In the United States a significant milestone in the policy to promote the transfer of university-developed technology to industry was the passage of the federal Bayh-Dole Act and Stevenson-Wydler Act in the U.S. These regulations – which gave the universities the right to obtain intellectual property rights (IPR) from federally funded research (Nelson 2001, Mowery et al, 2001, Mowery & Sampat 2005) – correlated with the adoption and the further development of IPR-related procedures and policies at universities (Branscomb et al. 1999; Van Looy et al., 2003).

The introduction of these procedures coincided with a surge in academic patenting in the US, tempting many to see this as positive evidence for Bayh-Dole. Nevertheless the causal impact of Bayh-Dole on the rise in "third mission" activities at universities remains empirically not yet established and controversial in the economic literature. For instance, Mowery & Sampat (2005) warn for a misreading of the empirical evidence on the importance of intellectual property rights in facilitating the “transfer” and commercialization of university inventions. “Inasmuch as patenting and licensing are rated by industrial R&D managers as relatively unimportant for technology transfer in most fields, emulation of the Bayh-Dole Act is insufficient and perhaps even unnecessary to stimulate higher levels of university-industry interaction and technology transfer. Instead, reforms to enhance inter-institutional competition and autonomy within national university systems, as well as support for the external institutional contributors to new firm formation and technology commercialization, appear to be more important”

8.2. Technology Transfer Offices

Following the rise of dedicated technology transfer offices at US universities, many European universities followed suit by setting up their own TTOs. In a number of countries this happened with the support of public subsidies.

Nevertheless, the evidence even for the US shows that most of the TTOs fail to break even, lacking a sufficiently large deal flow (Astebro & Bazzanini , 2011). Benchmarking within the EU specialized technology transfer offices there is no clear evidence on the effectiveness of these intermediaries and their role in improving industry science links (Polt, 2001). Most of the critical success factors for industry science links (such as appropriate incentive schemes and institutional settings, the level and orientation of R&D activities at both industry and science, legislation) cannot be shaped by the intermediaries themselves. They therefore often will fail to foster transfers if there exist other barriers to interaction. In the EU, most intermediary organizations are rather small and are therefore often below the necessary critical mass to be effective (Polt, 2001). There is also a danger that they will focus too much on the classic technology transfer (ie licensing and spin-offs), particularly if their mandate is to maximize the returns to the university from technology transfer activities.

8.3. Regional clusters; Science parks

In many industrialized countries, efforts to increase the national economic returns from public investments in university research have attempted to stimulate the creation of “regional clusters” of innovative firms around universities. These undertakings seek to stimulate regional economic development and agglomeration via facilitating the creation of “spin-off” firms to commercialize university technologies (OECD, 2002). These policy initiatives are motivated by the high-technology regional clusters in the United States. National and local governments in Europe have attempted to stimulate the formation of such clusters, eg via funding or tax credits for "science parks". At EU level, the European Institute of Technology, subsidized by FP7 & H2020 funding, provides a unique model with the potential for combining research, teaching and tech transfer in a symbiosis to yield spillovers on local economic development and beyond (see Box 3). Unfortunately there have not yet been any rigorous evaluations of realizations of the EIT potential for regional spillovers.

Box 3: European Institute of Innovation and Technology (EIT)

The European Institute of Innovation and Technology (EIT) was set up in 2008 to improve the triangle of research, education and technology transfer. Since 2010, 3 Knowledge and Innovation Communities are operational, set up with a time horizon of 7 to 15 years. KICs integrate partners from business, higher education and research in a structured entity with a results-oriented agenda each led by a CEO. Each KIC is organised around a small number of physical co-location centres spread across Europe (5 to 6 per KIC) where people can be brought together to work for significant periods of time, allowing for face-to-face interaction and regional synergies. The collaborative environment of the KICs and their physical co-location centres offer opportunities for shared activities in the fields of education, innovation and research. In the KICs and the co-location centres, universities are particularly important actors with education programmes around technology, entrepreneurship and technology transfer skills plus cross-disciplinary study programmes. Co-location centers are in most cases hosted in a higher education institution and supported by technology transfer organisations present within the HEIs;

Initial results from the existing colocation activities indicate potential for entrepreneurship and knowledge sharing. Co-location centres can accelerate growth in start-up activity providing a further boost to the impacts associated with entrepreneurial skills. Individuals within a co-location centre are able to use the expertise, infrastructure and capital to gain better awareness of market risks and opportunities. In terms of sharing and exchange of knowledge, co-location centres accelerate knowledge externalities and spill-overs at the local level. But the EIT structure also allows to connect the co-location centres, providing connections between regional hubs of excellence in Europe.

Despite the widespread interest in science parks, there is little evidence that supports the argument that the presence of universities somehow "causes" the development of regional high-technology agglomerations. And even less evidence supports the argument that regional or innovation policies of governments are effective in creating these agglomerations. The U.S. experience suggests that the emergence of such agglomerations is a matter of contingency, pathdependence, and (most importantly) the presence of other supporting policies (intentional or otherwise) that may have little to do with university research or the encouragement of university-industry linkages.

Moretti and Wilson (2013) investigate the effects of state-provided biotech incentives on the local biotech industry and the state economy. Although they find large and significant effects on the number of star scientists in the state and local employment in the sector it mostly seems the effect of relocation from other states. The authors cast doubt on the effectiveness of such incentives at the state level and point out that the "efficiency of these policies from the point of view of the nation as a whole is even harder to address".

8.4. INDUSTRY SCIENCE R&D COLLABORATION

Financial support for collaborative research receives the largest portion of public money for promoting industry science links and is still gaining in importance in most countries. The EU framework programmes for research and technology development also follow this line of support and represent major additional funding for collaborative research between universities and firms. Likewise in the US, the Advanced Technology Program (ATP) provides direct funding for pre-competitive generic cooperative research.

A more elaborate literature exists evaluating public support for R&D collaboration. The predominant question analyzed by this empirical literature is whether public subsidies crowd out private investment at the participating firm or whether they stimulate them. A few other studies also examine the impact of public subsidies on innovative performance and growth in recipient firms. Since neither the fact of applying, nor the fact of receiving a public subsidy can be viewed as random, the selection into such a process has to be taken into account (David et al (2000)). The more recent empirical literature, addressing this selection bias with proper empirical methodologies (matching and/or instrumental variables econometrics), rejects total crowding out. The vast majority of these studies find positive results on participating firm's R&D intensity or patent activity. For a more comprehensive survey of most recent studies, see Cerulli (2010). These studies however do not single out subsidies for R&D collaboration between industry and science from other forms of R&D collaboration.

Unfortunately, it is fair to conclude that in general we are still missing rigorous evaluations of the effects of government interventions to stimulate the impact of universities. The state of the literature is not yet sufficiently developed to support policy making with evidence indicating which policy instruments will be more effective to stimulate the contribution of universities to the economy.

The policy initiatives that seek to stimulate university-industry linkages all suffer from a lack of a proper evaluation strategy prohibiting systematic evidence collection on the causal effects of the policies. Most policies are looking for quick “success stories”, lacking a long term perspective needed to develop a triple helix eco-system. There are also mostly focused on a few targeted interventions, ignoring the need for a systemic approach with supporting institutions. Furthermore, the target of the policies is usually mostly narrowly focused on commercialization of university technologies, rather than broader contribution to economic development with other pathways.

9. CONCLUDING

The evidence reviewed in this report clearly shows the important role universities can and do play in economies at wide and for their local economies in particular, managing to reconcile their first and second mission of teaching and exogenous driven research with their third mission of contribution to (local) economic development. The pathways through which these third mission activities of universities materialize are manifold. The mode which is most often looked at by researchers, policy makers and the wider community and where most data are available is academic patenting. Evidence on academic patenting is widely available. It clearly shows a growth over time, but at the same time it shows how concentrated the phenomenon is in few institutions, few technology areas and on few academic patents with high (licensing) value. The other most often looked at mode, the one of faculty spin-offs, has less well developed databases available, but also shows the same skewedness. The evidence also clearly shows the importance of geographic proximity for the effects of patenting and spin-offs to materialize.

Although both modes receive most attention, they are however most probably among the least important gateways through which universities have an impact. Student spin-offs, graduate mobility and other more informal and collaborative modes with industry are more effective to impact the innovative performance of industry.

These findings cast further doubt on the utility of a one-size-fits-all approach to (regional) economic development that so many universities have been pursuing, with its focus on patenting, licensing, and startups. It calls for a broader view of the university's role in local economies – as creators, receptors, and interpreters of innovation and ideas; as sources of human capital; and as key components of social infrastructure and social capital.

Policy makers eager to boost the third mission of their universities, all too often look for quick "success stories" trying to emulate often US success stories, like Silicon Valley, which have taken a long time to develop. In addition they all too often focus their target on patenting, licensing and spin-offs, and on emulating policy instruments which target these modes, like Bayh-Dole reforms and technology transfer offices. But such policies can only properly play their role if embedded in a more systemic policy approach, which provides the framework conditions for all actors in the triple helix eco-system, universities and industry, to contribute to innovation based growth and job creation.

There are still many holes in our understanding of how universities contribute to economic prosperity. We need more research and more data. We don't understand how universities can square their multiple missions, without jeopardizing their unique position in the triple helix eco-system. We don't understand the degree to which universities are able to cause (local) economic development, as opposed to respond to economic development. We know very little of how and which firms internalize the transfer of knowledge from universities into their own innovative processes. We know very little of why companies and spin-offs tend to locate close to universities. We would like to know more about student start-ups. We would like to see more research on the mobility of (post-)graduates and researchers between universities and (local) firms as pathway for knowledge spillovers. Linking databases and unique identifiers for researchers are the way forward here, such as the linked employee-employer data. We are still lacking systematic evidence on the causal effects of the policies. We would like to know more about the effects of Bayh-Dole-type of policies and whether and which technology transfer intermediates work in various European countries. To progress, policy makers should be more serious about evaluating their instruments and support more systematic data collection on the various pathways for universities' contribution.

Box 4: Policy implications

- The most frequently used policy instruments for improving universities' contribution to innovation and growth are
  - Regulation of intellectual property rights
  - Supporting Technology Transfer Offices
  - Supporting "science parks"
  - Funding industry science collaboration
  - Stimulation of the formation of technology clusters
- The current stage of economic research evaluating these policy instruments is still far from being able to assess whether such policy interventions are indeed effective to stimulate the contribution of universities to innovation. Most studies grapple with establishing a causal link, identifying proper counterfactuals for the policy intervention. The policy initiatives that seek to stimulate university-industry linkages all suffer from a lack of a proper evaluation strategy prohibiting systematic evidence collection on the causal effects of the policies.
- Nevertheless, the evidence at hand suggests some lessons to be learned, already at this stage. Beyond the need for a proper evaluation strategy, policy should take a long-term perspective for developing a triple helix eco-system, avoiding the temptation of quick "success stories". Also to be avoided is a focus on few targeted interventions, ignoring the need for a systemic approach, supportive of all components of the triple helix eco-system and their interactions. A particularly dangerous policy practice is a target focusing only on the commercialization of university technologies, through licensing and spin-offs, ignoring the broader contribution to economic development with other pathways, most notably the training and mobility of human capital.
- Overall, the most salient policy recommendation that stems from this report is that policy makers should be more "innovative" in their search for effective policy interventions, venturing beyond the classic spin-off and incubator programs. At the same time, they should be more serious about evaluating their new and existing instruments. To progress, policy makers should support more systematic data collection and analysis on the various pathways for universities' contribution to economic prosperity.

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