INGENIO WORKING PAPER SERIES

ingenio CSIC-UPV
Institute of innovation and knowledge management

# The impact of one of the most highly cited university patents: formalisation and localization

*Joaquín M. Azagra-Caro, David Barberá-Tomás, Mónica Edwards-Schachter*

Working Paper Nº 2015-02

INGENIO [CSIC-UPV] Ciudad Politécnica de la Innovación | Edif 8E 4º | Camino de Vera s/n | 46022 Valencia
tel +34 963 877 048 | fax +34 963 877 991 | innco@ingenio.upv.es

# The impact of one of the most highly cited university patents: formalisation and localization

*Joaquín M. Azagra-Caro, David Barberá-Tomás*[1]*, Mónica Edwards-Schachter*[2]

INGENIO, CSIC-UPV (Spain)

**Abstract:** This paper examines the underlying mechanisms of knowledge diffusion and interrelationships between formal and informal channels attending to the localisation of spillovers between university and industry. With this aim we present a historical in-depth case study centred in one of the most highly cited university patents, developing and applying a theoretical approach that combines formalisation and localisation analytical dimensions. Our findings show how knowledge diffused through channels with different degrees of formalization (patent licenses, "pure" spillovers and consultancy contracts with the inventors). The case also evidences the pervasive delocalization of several knowledge diffusion channels and the complexity of achieving local impact, even at a privileged environment like California. The crucial diffusion mechanism channel stemmed from bidirectional knowledge flows between the university and a non-regional company, which provided the university with the specific fabrication capabilities needed to create an open-lab programme, which ultimately achieved local impact.

**Keywords:** Knowledge flows, Academic patenting, Technology transfer, Geographic R&D spillovers

**JEL Codes:** O31, O34

[1] Corresponding author: jobarto@ingenio.upv.es, Phone +34 963 877 048 Ext: 78496 Fax: +34963877991
[2] monicaelizabethedwards@gmail.com

# 1 Introduction

Patenting in research universities is associated with possible transfer and knowledge diffusion mechanisms that can contribute to regional economic development (Jaffe, 1989; Marion et al., 2012; Rothwell et al., 2013). One generalized argument explaining these effects is the creation of knowledge spillovers, where new information –a pure public good or protected by rights of exclusion– can generate benefits for society that accrue to economic agents other than the party that undertakes the research (Fischer & Varga, 2003; Rothaermel

& Thursby, 2005). From this perspective, university research is seen as being able to promote local knowledge spillovers (Breschi and Lissoni 2001; Feldman and Desrochers, 2003; Calderini and Scellato 2005). Spillovers and timely access to advanced scientific knowledge can explain performance differentials among firms and regions (Cockburn & Henderson,

1998; Zucker et al., 1998), being particularly relevant in the case of knowledge that produces radical or breakthrough innovations that catalyse industrial and societal change.

One analytical dimension generally chosen by research to study knowledge flows focuses on patent citations: backward citations oriented to measure the novelty dimension and forward citations in order to measure the impact dimension (Jaffe et al., 1993; Trajtenberg et al., 1997; Dahlin & Behrens, 2005; Henderson et al., 2005). However, the use of patents to capture the complex nature of knowledge flows is controversial and the question related to whether knowledge spillovers are bounded by geographical proximity or not remains elusive (Breschi et al., 2005; Jaffe & Trajtenberg, 2005; Li, 2014). Acknowledging the importance of spillovers and the inherent difficulty to explain and measure the 'invisibility' of knowledge flows, Krugman (1991) claimed for a renewed attention by economists to issues of economic geography. But more than two decades later, we still have little understanding about the channels and underlying mechanisms (both formal and informal) through which knowledge produced within the boundaries of universities gets transferred and translated into industry. If

we think that diffusion can be localised or delocalised, our understanding is even scarcer. Addressing this gap, this paper aims to examine the diffusion of knowledge related to a highly cited university patent, attending to the relationships between localization and types of channels (formal and informal) that allow the generation of spillovers. Jaffe et al. (1993) highlighted that case studies can be useful instruments to overcome the limitations of patent and citation data and provide with a more profound understanding about the geographical dimension of knowledge flows. With the objective of providing a true foundation for public policy and economic theorizing, they specifically referred to case studies of highly cited patents: 'in future work we plan to identify a small number of patents that are extremely highly cited. It is likely that such patents are both technologically and economically important. Case studies of such patents and their citations could prove highly informative about both the mechanisms of knowledge transfer, and the extent to which citations do indeed correspond to externalities in an economic sense' (Jaffe et al., 1993, p. 597).

Answering to this claim, we perform an in-depth case study, being our principal objective to understand the underlying mechanisms of knowledge diffusion throughout the analysis of formal and informal mechanisms, like licenses and spillovers, and their possible complementarities. In order to reach this purpose, we build upon theoretical insights and find evidence on the relation between localisation and type of channels (formal and informal) in the knowledge related to a university patent. This example will not only cover the mentioned academic gaps, but it will have also considerable didactic potential for teaching about the complex nature of patents and knowledge diffusion phenomena.

Our starting point was to find a university patent with an outstanding account of diffusion, relying on citation data under the presumption that a highly cited university patent will have many stories to tell. In order to conceptualize these stories within the framework of university-industry interaction literature, we propose an analytical approach combining theoretical conceptual lenses regarding formalisation mechanisms and localisation (the geographic spread of knowledge spillovers). This theoretical framework is described in Section 2. Section 3 presents the methodology applied and later sections will head us to the empirical part, explaining our findings and the conclusions.

# 2 Literature review and theoretical approach

To start with, literature focused on case studies of university patents is scarce. Colyvas et al. (2002) analyse the role of intellectual property rights and university technology transfer offices in facilitating technology transfer in eleven inventions created at

Columbia University and Stanford University. The work was based on previous invention reports realized by these universities to explore their potential commercial value, considering the changes introduced by the Bayh-Dole Act in 1980. The act provided a regulation framework to achieve rapid and widespread technology transfer from university to industry. In this paper, Colyvas et al. (2002) summarise descriptions of the cases and their differences in terms of the technology field, the nature of the knowledge that the underlying research intended to generate, and the proximity of the research goals to perceived practical needs. The context of most of these case studies did not correspond to the typical chasm –implicitly or explicitly– attributed in numerous writings regarding university-industry technology transfer (Anderson et al., 2007; McAdam et al., 2010; Marion et al., 2012). One distinctive characteristic was that the university researchers involved in the inventions were members of a network of scientists also involving people from the industries that could likely benefit from successful research results.

'In many of the cases, it is clear that at least strategically placed people in industry knew about the project from its inception. In some cases that was because industry funding went into the project; but in some of the cases it was simply because university scientists and industry scientists roughly communicated to each other what they were doing' (Colyvas et al., 2002, p. 64).

In our view, their findings challenge conventional wisdom: diffusion of academic inventions other than embryonic not requires strong Intellectual Property Rights (IPRs), and technology transfer offices are not strictly necessary if the patent is interesting enough for industry. Regarding the opinion about the existence of closely links favouring knowledge flows between the realms of science and industry, it seems to depend on the activity sector[3] (Narin, 1994; Colyvas et al., 2002).

One of the most famous university patents, Cohen-Boyer's recombinant DNA patent, applied for by Stanford University (filed 1974, granted 1980, expired 1997) has merited particular attention. Feldman et al. (2007) explore how it was an example of successful technology transfer strategy thanks to an appropriate diffusion plan, aligned with the

[3] In biotechnology there is essentially no time lag between science and technology. The inventor works in the university or the government lab in the morning in the United States, and he works at or consults with a private company in the afternoon, and the time lag between his academic research and his private inventive activity is lunch!' (Narin, 1994, p. 150-1).

university's goals. This pioneering process was not without conflicts and negotiations, and did not necessarily foster technology transfer, but became a model for commercialization of research and royalty revenues (Hughes, 2001). None of these works focuses on interaction channels other than licensing or on localization aspects and they not include analysis of patent citation records. A validation study of the use of patent citation analysis in the case of highly cited U.S. patents realised by Albert et al. (1991) shows the strong association between patent citation indicators in assessing the relevance of a technology. However, analyses of citation classics are more frequent in the case of academic publications (e.g. Kresge et al., 2005).

To our knowledge, ours is a novel micro-level study of a university patent chosen of the basis of its high number of citations jointly with the analysis of localisation phenomena and other informal diffusion mechanisms. In what follows we present the analytical approach we applied in our case study trying to capture knowledge flows embedded in university-industry interrelationships.

## *2.1 University-industry interaction Axis I: formalization of knowledge diffusion*

Previous literature recognizes the existence of many types of interactions (Meyer-Krahmer and Schmoch, 1998), linkages (Rappert et al., 1999) and instruments of cooperation between universities and firms (Azagra et al., 2006; Abramo et al., 2012). They can be informal (exchange of ideas through networking, barter relationships, etc.) or formal (patent licenses, consultancy, R&D contracts, collaborative research, joint academic programmes and studentship, etc.). The characterisation of 'formal' or 'informal' is usually determined according to the presence or absence of a contract (use of equipment, testing…) and explicit knowledge codification. Geuna and Muscio (2009) performed a critical literature review of knowledge transfer, showing the scant attention paid to the study of informal mechanisms and interactions and the difficulties to their institutionalisation. Their review demonstrate the non- existence of robust evidence on how much (or what kind) of knowledge is transferred to companies via formalised instruments and/or intermediaries, such as a knowledge transfer offices and what is transferred directly by university staff.

Informal contacts are highly valued among academic researchers, often more than formal interaction. Better than considering formal and informal relations as substitutes, we should understand that informal relations usually precede or initiate formal projects (Faulkner and Senker, 1994; Colyvas et al., 2002). However, universities are eventually adopting linkages that are more formal. This does not necessarily affect informal linkages because firms that maintained them before continue to maintain them, although they sometimes notice that faculty negotiate in market terms that they do not master, because "the desire for universities to be more commercially relevant then does not necessarily equate with them being commercial per se" (Rappert et al., 1999: 882). In developed countries, like Germany, academics show a preference for two-way as against one-way flows in interactions (Meyer- Krahmer and Schmoch, 1998), although in a European region with low absorptive capacity there is a certain tension between the two types of flows (Azagra et al., 2006).

Hence, diffusion channels can be classified according to their degree of formalization – sponsorship of more formalized ones raising concerns about interferences into the spontaneity of university researchers to draw benefits from industry, where patent licenses are included as formal mechanisms.

Meyer-Krahmer and Schmoch (1998) state that actually, when compared to other channels, university patenting may not be representative of science-industry interaction. University patenting can deteriorate formal links because faculty members overestimate their industrial property and contractual agreements in this matter can be very difficult (Rappert et al., 1999). Azagra et al. (2006) find that faculty members do not place much value on patent licensing as an instrument of cooperation and maintain that the contribution of this instrument to cooperation objectives is very limited. On other hand, Dosi et al. (2006) state that income flows from licensing are quite small as compared to the overall university budget and even unable to cover the administrative costs of the technology transfer office in charge of them.

Academics do not rank patents high compared to other outputs of collaboration with industry (Goddard and Isabelle, 2006). This disbelief may need reconsideration since, as we will show through our case example, a highly cited university patent is likely to be closely related to other formal and informal mechanisms of knowledge transfer. In this respect, agreeing with Cohen et al. (2002) and Arundel and Geuna (2004), firms generally rely on a variety of sources of information on public research outputs.

## *2.2 University-industry interaction Axis II: localization of knowledge diffusion*

Since the seminal contributions of Jaffe (1986, 1989) there has been a widely recognition on the influence of spatially mediating university spillovers on firms' innovation activities across time. Jaffe et al (1993) reported significant localisation of knowledge spillovers at regional level and found that knowledge localisation fades slowly over time. Spillovers take place because university research has some characteristics of a public good whose positive externalities firms may be able to capture as 'technological opportunities' (Jaffe, 1986; Klevorick et al., 1995). The empirical positive effect of university R&D on innovation counts supports this idea. The effect is larger, the shorter the spatial distance between firms and universities (Anselin et al., 1997). However, Varga (2000) and Trajtenberg (2005) maintain that regions need a "critical mass" of agglomeration in order to expect substantial local economic effects of academic research spending. There is also high variation of this effect across sectors, electronics presenting the largest localised spillovers (Anselin et al., 2000). Externalities from universities also lead to regionally localised formation of new firms (Acosta et al., 2011) but play a significant albeit small role in determining regional patent production (Buesa et al., 2010). On other hand, most firms experiment difficulties to adapt to technological change when the new knowledge is disruptive in the sense to be radically different (Shibata, 2012).

Various authors contributed with empirical studies to this focus on the 'geographical dimension' of knowledge spillovers. Branstetter (2001) obtained micro-econometric evidences comparing national and international knowledge spillovers in US and Japan. Fischer and Varga (2003) analysed empirically the regional effects of mediated knowledge spillovers from university in high tech industries in Austria. In the US context, Jaffe et al. (1993) found that citations to domestic patents are more likely to be domestic, and more likely to come from the same state and region as the cited patents, with significant impact at the local level. They also show that there is no evidence that more 'basic' inventions diffuse more rapidly than others and localization fades very slowly over time.

Some of the influences expressed by the positive association between university R&D and innovation counts are not attributable to externalities. Deliberate efforts by firms are necessary to translate university research into marketable inventions, e.g. reading codified knowledge from universities, or engaging into partnership with academic researchers. Hence, diffusion channels can be classified according to their degree of localization.

Typical measures to track deliberate efforts (with many caveats, which we skip for brevity) are university-industry joint research projects and university citations found in firm patents. Increasing business expenditure on R&D has a positive influence on firm participation in joint research projects with regional universities (Azagra-Caro et al., 2013), although none on firm citations to regional universities (Acosta et al., 2014). This evidence allows for an inside/outside the geographical unit perspective, which complements the usual focus on distance.

Firm citations to universities can be to a patent like the focal patent of our study, which may help understand why a citation takes place and if it represents a spillover (knowledge in the air), a use of codified information (having read the cited papers or patents) or face-to-face contact with academics. In addition, when we situate the story of knowledge embodied in the focal patent along Axis II (localization), we will be in a position to reflect about whether the impact of academic research is so automatically localized as the spillover literature suggests.

## *2.3 The two axis combined*

Qualitative studies of patents enhance understanding about the diffusion channels and geographical spread of knowledge related to a patent (Romero de Pablos, 2011). Figure 1 presents a visual representation of our conceptual approach combining these two aspects. It acknowledges that academic knowledge can diffuse through from most formalized and local mechanisms (upper right quadrant) to least formalized and non-local mechanisms (lower left quadrant, with intermediate combinations (in the other two quadrants).

{Figure 1 around here}

Most studies referred in the previous sections have shown that we can fill in each quadrant with mechanisms emanating from different pieces of knowledge, e.g. knowledge codified and related to patents. We are going to illustrate that separating those pieces is harsh, and that even with the story related to a single university patent, we can find examples of the diffusion phenomena and the complex dynamics of knowledge flows for each quadrant. Of course, the choice of a highly cited patent is convenient because of the likelihood of finding many stories behind. Moreover, our analytical framework constitutes an oversimplification, because geography is just one dimension of proximity and others are equally relevant in explaining localization, namely cognitive, organizational, social and institutional proximity (Boschma, 2005). We believe there is still value in conceptualizing the relation between just one type of proximity and formalization of diffusion channels, but future research could lead to more complex models.

# 3 Methodology

We adopted a qualitative research methodology and in-depth case study because of the exploratory nature of this work and the need for rich and comprehensive information that could facilitate the comparison of our theoretical insights (Strauss & Corbin, 1990; Yin, 2003). Our case study also involves an ample literature review, the use of patent databases and other abundant secondary information sources together information obtained from three in-depth interviews. A case study is a history of a past or current phenomenon that draws on multiple sources of information and evidence, being a powerful instrument that enables to capture the complex dynamic of the innovation process (George and Bennett, 2005). According to Shibara (2012) case studies make it possible to explain the relevance and cause-and-effect relationships of a variety of observations. We conducted in-depth interviews from July to October 2013, with the principal actors involved in the generation of this patent using a hermeneutic-dialectic method where the interviewer played an active role, and interviewer and respondent shaped the interview ‘content’ together (Jørgensen and Phillips, 2002). This experience provided the authors with direct knowledge and detailed information with which the accuracy of the empirical analyses in this research was enhanced.

Regarding the identification of our analytical unit of study, i.e. our highly cited patent, it is necessary to mention that this task is not straightforward, because citations are not codified by type of institution. However, we rely on a database that was built precisely with that purpose by the Institute of Prospective Studies (IPTS). It covered European Patent Office (EPO) filings applied for by EU27 applicants in period 1990-2007 (Patstat and Web of Science informed the database). The data gathers over 24,000 university citations (around 66 per cent to patents, 33 per cent to papers). We identified those most frequently cited and crossed the information in Espacenet (Table 1). The one with the highest number of references was patent US5025346: “Laterally driven resonant microstructures”. The University of California filed it at the United State Patent and Trademark Office (USPTO) in 1989. To give an idea of its importance, notice that it has 430 citations versus the 342 citations of the famous Cohen- Boyer patent (US4237224: “Process for producing biologically functional molecular chimeras”, referred by Reimers and Hughes, 1998; Nelson, 2001; Feldman et al., 2007, etc.), despite the latter was granted much earlier.

{Table 1 around here}

For our historic analysis, as we commented before, we consider secondary sources and three in-depth interviews, with two inventors (both are now Professors of Engineering in important universities in the US West Coast and have held various science policy positions, as Director of the National Nanotechnology Infraestructure Network, and with an outstanding researcher in the same field (former Director of the Berkeley Sensor & Actuator Centre, BSAC). BSAC is an institute founded in 1986 –where research related to the patent was conducted, during late 80’s– and constitutes an example of a “triple helix” between industry, university and government (Etzkowitz and Leydesdorff, 1995). BSAC former director was also a long-term collaborator of one of the patent inventors and Program Manager for the MEMS Program at the Defence Advanced Research Projects Agency (DARPA). All interviews were transcribed and followed up by several emails asking specific questions arose when reading the transcription. We illustrate some of the qualitative finding with the study of forward citations of the patent (Source: Patstat, October 2012 edition: 375 citations).

# 4 The focal patent

Most academic patents, especially if owned by universities, belong to pharmaceuticals and biotechnology (Lissoni et al., 2008). Existing case studies tend to focus around these fields (Colyvas et al., 2002; Feldman et al., 2007), being the patent named “Laterally driven resonant microstructures” an exception. It is curious that our focal patent does not form part of the most representative technology of university patents.

The focal patent deals with a specific form of micro sensors and actuators called micro electromechanical systems (MEMS since now), based on the operational principle of the electrostatic force. This force is bigger enough at the nano and micro levels to produce relative movements between the elements of the devices, which are then capable to identify an alteration in the environment (sensor) or transform an alteration in a physical movement (actuator). Instead of the previous engineering effort to reduce size and power while simultaneously increasing the performance of a diverse set of electromechanical systems, the MEMS radically transformed the scale, performance and cost of these systems by employing batch-fabrication techniques and the economies of scale successfully exploited by the IC industry (Trimmer, 1996; Judy, 2001). Specifically, MEMS technology enabled many types of sensor, actuator and system to be reduced in size by orders of magnitude, while often even improving sensor performance (e.g. inertial sensors, optical switch arrays, biochemical analysis systems, etc.). The historical context of MEMS where our patent emerged is dependent on the development of micromachining processes whose principal hits are detailed in Table 2.

{Table 2 around here}

Although we are aware that not all inventions are patentable, not all inventions are patented, and the inventions that are patented can differ greatly in "quality" and/or in the magnitude of inventive output associated with them (Breschi et al., 2005), we consider that the patent US5025346 represent a disruptive invention and fits with our intention to explore the dynamics of knowledge flows within the MEMS development framework.

> *"Before MEMS was named in 1987 - we kind of named the field - in Europe it would be microsystems. Nano systems in the U.S. it's MEMS or NEMS, and in Asia. But it's certainly the case that there was pioneering work in Japan, Holland, Europe and the U.S. going back into the '60s. But in the '80s - '70s and '80s - people were beginning to think of things that were beginning to be more manufactureable. You know, using integrated circuit technology for MEMS, for micromechanical structures. And people had made even starting in the '60s if you put a voltage across two plates they pull and you can move them" (RH, inventor)*

This invention allowed the creation and improvement of an impressive range of applications. One of the most important original applications was the improvement of existing accelerometers, i.e., sensors for reporting vibrations in many engineering applications, from turbines to seismic activity identification. Later, this technology was essential to develop a new generation of airbags. Cardwell (1995) describes as one of the most important elements of Watts' steam engine its ability to perform circular movements instead of the linear movements performed by the previous Newcomen engines. In this sense, the focal patent can be described as an anti-Watt breakthrough. It is worth noting that despite the existence of an interrelated ecosystem of interactions between scientists and industrial members, the inventors suffered a widespread misunderstanding.

> *"... the spirit was very, very much a bunch of very courageous pioneers all doing something that they loved and they had no idea if it was going to be a big success or a small success or anything else like that... Imagine a world in which companies will laugh when they first heard of it. Ah, MEMS is nothing more than pictures of ants riding around on little gears and boy, what a stupid exercise that will never have any practical purpose" (BSAC Director).*

> *"if you wanted to make a big contribution in MEMS it was insufficient just to do the research. You had to help organize conferences and you had to convince journals that they wanted to publish these papers. You had to help form your own journal, which is one of the activities I was involved in the process of foundation of the MEMS journal. And I served as the - what did they call it? The big boss - the executive editor" (BSAC Director)*

The patent was one of the first granted to UC Berkeley after the Bayh-Dole Act of early 80's, which allowed US universities to apply for patent protection in a context of major institutional changes oriented to strength of patent enforcement in the US that might have been expected to increase the propensity to patent (Caballero and Jaffe, 1993; Colyvas et al., 2002). However, as one of the interviewees explained us, experience on administrative issues regarding university patenting was scarce in every stakeholder involved: inventors, university administration or lawyers.

> *"BSAC, at that time, was NSF-funded, with industrial membership. So, it is like a freeway collaboration, and NSF put in some funding. The industry put in some money as a BSAC member" (WT, inventor)*

> *"I think it was 1986 when BSAC was formed - plus or minus a year; I think it was '86, '85. So, at that time there were four industrial members - five industrial*

*members - and it seemed small because there's 30-something today but these five members were extremely committed to micro sensors" (RH, inventor) "At that time, as far as I can remember, BSAC members, the company members have started looking into collaboration by, you know, using some of our facility to do fabrication work... At that time, I don't remember seeing any spinoff company or anything from our research" (WT, inventor)*

This early stage can explain some particularities of the case, which apparently contradict common knowledge in the field: the license of the patent was not part of any specific industry-university collaboration project, and the inventors did not participate in knowledge transfer activities directly related with the license neither the generation of other key technology transfer mechanism, i.e., the creation of a University spin-off or the founding of new technology-based ventures (O'Shea et al., 2007; Pries and Guild, 2007; Abramo et al., 2012)[4]. Indeed, inventors were not officially informed about the identity of the licensee: they just received the check for royalties in their bank accounts. This means a limitation for our license data: inventors told us the identity and number of licensees based in their knowledge of the field.

The focal patent was born at the auspices of the Bayh-Dole Act. One of the inventors reported that without this legal change, the application would have probably not taken place. Some evidence shows that University of California was very active in patenting before the passage of the Bayh-Dole Act, so the impact of this legal change would have been minor (Mowery and Ziedonis, 2002). Our case seems to refute so.

Figure 2 shows the growing path of citations to the focal patent during its first ten years of grant. It reached the peak in 2001 and descended afterwards. This inverted U-shape profile is typical from patent citations, with the average citation peak at five years –more valuable patents reaching the peak later, so the focal patent is considerably valuable.

Figure 3 breaks down citations by geographic origin: from same region (regional) and from other regions' (non-regional) patents. Non-regional citations predominate and largely replicate the aggregate picture shown in Figure 2, with a peak in 2001. Regional citations have low levels and are mostly post-cyclical until 2002, shortening distances to

---

[4] A detailed situation of the University of California and a comparison of the spin-off rankings of US universities from 1980 to1994 and 1995 to 2001 are included in O'Shea et al. (2007, p. 4)

non-regional citations ever after. Hence, the focal patent is characterised for having had a leading delocalised impact in its first years.

{Figure 3 around here}

# 5 Filling in the four quadrants of knowledge diffusion

Figure 4 depicts how different diffusion channels related to the focal patent fit into the quadrants of Figure 1. The next sub-sections develop the stories behind each quadrant.

{Figure 4 around here}

## *5.1 Higher formalised channels, lower localisation*

One mechanism which fits in this quadrant is patent licensing: it is a highly formalized channel of knowledge transfer, and in our case licensees were not in the same region as the patenting research institution. This research institute, the BSAC, as we mentioned before, was founded in 1986 to leverage the opportunities offered by the new institutional environment for university-industry relationships created by the Bayh-Dole Act. It was located in UC Berkeley, which got funding from the National Science Foundation, dependent on the US Federal Government. At the same time, BSAC had several industry partners, which contributed with annual fees in charge for priority in licensing the new technologies developed by BSAC, representing an outstanding example of the Triple Helix phenomenon. The patent was only licensed in early 2000s, to MEMS Solutions3. Inventors felt that the patent, granted in 1991, was scientifically relevant very soon, but concrete applications took more time to be developed:

> *"We waited and waited and waited - there was academic research, other patents referencing it -but no one was into production"* (RH, inventor)

The patent expired and inventors felt that it did not provide them with considerable royalties ("at the peak, it was 2% of my full income"). Honeywell is among the top citing companies of the focal patent, but despite holding the license, it is not the first but the fourth in the citation ranking (Figure 5). ). Other companies overcome MEMS Solutions in number of citations, Sensor Technologies at the forefront.

{Figure 5 around here}

Precisely Sensor Technologies applied another transfer mechanism placed in this quadrant: contracted consultancy work. This is highly formalized as involves a contract, and also in this case was not localized, as involved another company, which was not located in the same region as the patenting university, i.e., Sensor Technologies. After the patent was granted, the second inventor was involved in various consultancy projects with Sensor Technologies about MEMS technology[5]. There are many cites to focal patent in later patents applied for by Sensor Technologies (Table 3). In 5 out of 39 cases (13%), second inventor of focal patent was also the inventor in Sensor Technologies' patents, which illustrates well the knowledge transfer mechanism described here.

{Table 3 around here}

## 5.2 Lower formalized channels, lower localization

Labor mobility populates this quadrant. After finishing his PhD in BSAC the first inventor was hired by White Research Laboratory in Dearborn, Michigan, and as the Sensor Research Manager. There he developed air bag applications related to the comb drive technology. This mechanism presents low formalisation, as there was no specific instrument to regulate hiring BSAC members by industrial partners, such as White Research Laboratory. Neither is it localized, since the company and the patenting institute were in different regions. Interestingly, the future first inventor's patents have few self-cites compared to second inventor (only 3).

Another mechanism of knowledge transfer of MEMS technology is related with "pure" spillovers from the university codified knowledge to the industry. As the second inventor told us, Sensor Technologies developed in early 90's an accelerator which was directly derived from his PhD thesis, published in 1984.

> *"I remember –and here's the interesting complexity– Sensor Technologies introduced a revolutionary accelerometer in 1990, 1991 called the XL50, okay? And in fact, the way they made it was derived from my Ph.D. thesis" (RH, inventor)*

This represents an extremely low formalized mechanism of knowledge transfer with a company outside the university region.

[5] We have anonymized the name of the three main companies involved in licenses and other knowledge transfer mechanisms.

## *5.3 Higher formalized channels, higher localization*

This quadrant is especially interesting in our case, as it involves the most significant local impact. It involved the creation of an "open access micro lab", were local entrepreneurs could experiment with the fabrication technologies related with MEMS:

> *"In the Berkeley campus we had the micro lab and we had a program by which start-ups and companies could come and build prototypes in our lab… Berkeley was the first place that had this open access for micro labs. So, the entrepreneurs started to work over there"* (BSAC Director)

In turn, the entrepreneurial developments started in BSAC micro fabrication labs were decisive for the development of a local MEMS industry, which as we have seen was located exclusively outside California in previous years.

Crucially, the development of the fabrication micro lab was the result of the collaboration with Sensor Technologies, a company that was heavily involved in MEMS consultancy with BSAC researchers. This collaboration allowed BSAC to improve its fabrication capabilities: "it was the next accelerator you had a very short path from idea to product". Interestingly, this industry-university spillover concerning MEMS fabrication technology was recognized as a "low formalized" mechanism:

> *"So, we learned a lot about fabrication processes, and we learned how to tune our fabrication processes, but the Berkeley Microlab was built independently, and so the 'crossover' was primarily knowledge about fabrication process details, and not the fabrication equipment itself"* (BSAC Director)

This illustrates what we understand as "complexity of local impact" of knowledge transfer: a company which was a strong collaborator in MEMS technology was the responsible of the "inverse spillover" from industry to university which allowed to create a lab which in turn was decisive in the development of an ex novo local industry of MEMS.

Patent citations to the focal patent further elucidate the complexity of local impact in this case: the typical distance decay of geographical spillovers would let us predict that national citations are more frequent than international, and that regional citations are more frequent than national, non-regional ones. In our case (Table 4), we can verify the first part, as international citations are fewer than national citations: 37% vis-a-vis 63%.

However, the second part is not true: within national citations, non-regional ones predominate over regional (37% versus 18%). Local impact was lower than national despite the spillover literature suggesting the opposite would occur.

{Table 4 around here}

### *5.4 Lower formalised channels, higher localization*

In this last quadrant we include not acknowledged local spillovers. Applicants may use knowledge embodied in previous patents without disclosing it through citations because of unawareness or strategic behaviour. Examiner duty is then to add citations that may refute applicants' novelty claims. Examiner citations tend to be more delocalised than applicant ones, because the former perform technology search worldwide whereas the latter may face cognitive boundaries (Thompson, 2006; Alcacer and Gittelman, 2006; Criscuolo and Verspagen, 2008; Azagra et al., 2011). Table 5 shows that our focal patent reflects such a typical case: examiners add higher citation shares to patents applied for outside California, especially to foreign ones. Higher applicant citation shares correspond to California. Interestingly, still one third of citations are added from the examiner. This implies that there are informal diffusion channels in the region which make other local technology build on the focal patent, even without acknowledgement.

{Table 5 around here}

## 6 Discussion: university patents as the tip of the iceberg

Diffusion of knowledge related to one of the most highly cited university patents did not take place mainly through its license. We can speculate, without much risk of being wrong, that the costs of maintaining a laboratory like BSAC overweight licensing income, so it is difficult to justify patents based on monetary benefits. In this sense, we agree with the largely accepted idea that university-owned patents are just the tip of the iceberg of technology transfer (Audretsch et al., 2006; Gopteke, 2006, 2008; Ramos and Fernández, 2012). Knowledge embodied in university research results has many diffusion channels and focusing on patenting needs not be the most successful one.

Nevertheless, our study illustrates that even one single university patent may be intricately related to other technology transfer mechanisms, which would have never developed (or not without substantial delay) in the absence of that patent. From this point of view, the “tip of the iceberg” contributes to the formation of the “mass below the surface”. The limits between both blur and the iceberg metaphor becomes somehow inaccurate: university patents as the ace of diamonds could be better, singling out that they form part of a deck –sometimes they start the count, sometimes they finish it; in some games they are the triumph, in some others they are not.

# 7 Conclusions

Our results show some underlying patterns of spillovers, and of the complexity of achieving local impact. Knowledge spillovers happened through formal mechanisms (patent licensing or consulting) but also very importantly through informal ones, as labour mobility or even “pure” spillovers, that is, knowledge absorption by the companies of university research knowledge in form of scientific articles or PhD thesis not involving any economic transaction (captured also more “quantitatively” with backward patent citations). Thus, the case shows that complacency on high numbers of patents or disappointment by low volume of licenses do not give an accurate account of university contribution to technological innovation.

Local impact of the technology developed by the university was highly complex (Figure 6). It was indirectly achieved through collaboration with companies outside the region: agreements about fabrication of this technology between the university and those companies allowed the university to create a laboratory for fabrication opened to local entrepreneurs, which then were able to start new companies in a region were previously businesses based on this kind of technology were absent.

{Figure 6 around here}

The company to which the focal patent was licensed was not the company that developed further the related technological competences. The knowledge embodied in the technology had been used also by a second company, via spillovers of the PhD thesis of one on the inventors. Once the patent was granted, this second company developed related technologies further, by applying internal competences and hiring one of the inventors for consultancy and all this happened beyond the region. It was necessary the development of an institutional support –a presence of a laboratory in the region- to achieve some degree of local impact.

Globally, our case study emphasises that knowledge related to a patent matters more than the patent itself for the knowledge diffusion phenomena. Hence, having started by looking also for other codified channels of that embodied knowledge, like journal articles, would have been appropriate. Actually, even our focal patent case highlights the importance of publications like PhD theses. We accept this limitation and future research should take care of highly cited academic papers in patent documents. We have also neglected some aspects of the strategy of the inventors when their university applied for the focal patent have been neglected, e.g. to what extent did the inventors participate with the technology transfer office in the licensing process? This question merits additional research. It was outside the scope of this paper, which aimed at illustrating how diffusion mechanisms can be placed in the four quadrants of our conceptual model, and that is regardless the strategic concerns of the actors involved, beyond general diffusion purposes.

# References

Abramo, G., D'Angelo, C. A., Ferretti, M., & Parmentola, A. (2012) An individual‐level assessment of the relationship between spin‐off activities and research performance in universities. R&D Management, 42, 3, 225-242.

Acosta, M., Azagra-Caro, J. M. & Coronado, D. (2014) Access to universities' public knowledge: Who's more regionalist? *Regional Studies*, forthcoming.

Acosta, M., Coronado, D. & Ferrándiz, E. (2011) University spillovers and new business location in high- technology sectors: Spanish evidence. Small Business Economics, 36, 365–376.

Albert, M. B., Avery, D., Narin, F., & McAllister, P. (1991) Direct validation of citation counts as indicators of industrially important patents. Research Policy, 20, 3, 251-259.

Alcacer, J., & Gittelman, M. (2006) Patent citations as a measure of knowledge flows: The influence of examiner citations. The Review of Economics and Statistics, 88, 4, 774-779.

Anderson, T.R., Daim, T.U. & Lavoie, F.F. (2007) Measuring the efficiency of university technology transfer. Technovation, 25, 5, 306–318.

Anselin, L., Varga, A. & Acs, Z. (1997) Geographic Spillovers between University Research and High Technology Innovations, Journal of Urban Economics, 42, 3, 422–448.

Anselin, L., Varga, A. & Acs, Z. (2000) Geographic and sectoral characteristics of academic knowledge externalities. Papers in Regional Science, 79, 4, 435-443.

Arundel, A. & Geuna, A. (2004) Proximity and the use of public science by innovative European firms. Economics of Innovation and New Technology, 13, 6, 559–580.

Audretsch, D. B., Aldridge, T., & Oettl, A. (2006) The knowledge filter and economic growth: The role of scientist entrepreneurship (No. 1106). Papers on entrepreneurship, growth and public policy.

Azagra-Caro, J. M., Archontakis, F., Gutiérrez-Gracia, A., & Fernández-de-Lucio, I. (2006) Faculty support for the objectives of university–industry relations versus degree of R&D cooperation: The importance of regional absorptive capacity. Research Policy, 35, 1, 37-55.

Azagra-Caro, J. M., Mattsson, P., & Perruchas, F. (2011) Smoothing the lies: The distinctive effects of patent characteristics on examiner and applicant citations. Journal of the American Society for Information Science and Technology, 62, 9, 1727-1740.

Azagra-Caro, J.M., Pontikakis, D. & Varga, A. (2013) Delocalisation patterns in University-Industry interaction: Evidence from the 6th R&D Framework Programme. European Planning Studies, 21, 10, 1676-1701.

Boschma, R.A. (2005) Proximity and innovation: a critical assessment. Regional Studies, 39, 61–74.

Branstetter, L. G. (2001) Are knowledge spillovers international or intranational in scope?: Microeconometric evidence from the US and Japan. Journal of International Economics, 53, 1, 53-79.

Breschi, S.; Lissoni, F. & Montobbio, F. (2005) The geography of knowledge spillovers: conceptual issues and measurement problems. In S. Breschi and F. Malerba (Eds.). Clusters, networks, and innovation. Pp. 343-371. Oxford University Press:New York, USA.

Bryzek J. (1996) Impact of MEMS technology on society Sensors Actuators. A 56 1–9.

Buesa, M., Heijs, J. & Baumert, T. (2010) The determinants of regional innovation in Europe: A combined factorial and regression knowledge production function approach. Research Policy, 39, 6, 722-735.

Caballero, R. J., & Jaffe, A. B. (1993) How high are the giants' shoulders: An empirical assessment of knowledge spillovers and creative destruction in a model of economic growth. In O. Blanchard and S. Fischer (Eds.). National Bureau of Economic Research Macroeconomics Annual 1993, Volume 8 (pp. 15-86). MIT press:USA.

Cardwell, D. S. L. (1995) Wheels, clocks, and rockets: A history of technology. WW Norton & Company.

Chang, Y. C., & Yang, P. Y. (2008) The impacts of academic patenting and licensing on knowledge production and diffusion: a test of the anti□commons effect in Taiwan. R&D Management, 38, 3, 321-334.

Cockburn I.M. & Henderson R. M. (1998) Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery, Journal of Industrial Economics XLVI, 157-182.

Cohen, W.; Nelson, R. R. & Walsh, J. P. (2002) Links and impacts: The Influence of public research on industrial R&D. Management Science, 48, 1, 1–23.

Colyvas, J.; Crow, M.; Gelijns, A.; Mazzoleni, R.; Nelson, R. R.; Rosenberg, N. & Sampat, B. N. (2002) How Do University Inventions Get Into Practice? Management Science, 48, 1, 61-72.

Criscuolo, P., & Verspagen, B. (2008) Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. Research Policy, 37, 10, 1892-1908.

Dahlin, K. B. & Behrens, D. M. (2005) When is an invention really radical? Defining and measuring technological radicalness. Research Policy, 34, 5, 717-737.

Dosi, G., Llerena, P., & Labini, M. S. (2006) The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called 'European Paradox'. Research Policy, 35, 10, 1450-1464.

Etzkowitz, H., & Leydesdorff, L. (1995) The Triple Helix--University-industry-government relations: A laboratory for knowledge based economic development. Easst Review, 14, 1, 14-9.

Faulkner, W., & Senker, J. (1994) Making sense of diversity: public-private sector research linkage in three technologies. Research Policy, 23, 6, 673-695.

Feldman, M. P. & Desrochers, P. (2003) Research universities and local economic development: Lessons from the history of the Johns Hopkins University. Industry and Innovation, 10, 1, 5–24.

Feldman M. P.; Colaianni, A. & Liu, C. (2007) Lessons from the Commercialization of the Cohen-Boyer Patents: The Stanford University Licensing Program. In A Krattiger, R. T. Mahoney, L Nelsen, et al. (Eds.). Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices. MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A.

Fischer, M. M., & Varga, A. (2003) Production of knowledge and geographically mediated spillovers from universities. The Annals of Regional Science, 37, 2, 303-323.

George, A. L. & Bennett, A. (2005) Case studies and theory development in the social sciences. MIT Press, Cambridge, M. A.;

Goddard, J. G., & Isabelle, M. (2006) How do public laboratories collaborate with industry? New survey evidence from France. In DRUID summer conference (pp. 18-20).

Geuna, A., & Muscio, A. (2009) The governance of university knowledge transfer: A critical review of the literature. Minerva, 47, 1, 93-114.

Göktepe-Hultén, D. (2008) A theoretical framework for understanding university inventors and patenting (No. 2008, 031). Jena economic research papers.

Goktepe, D. (2006) Identification of University Inventors and University Patenting Patterns at Lund University: Conceptual-Methodological & Empirical Findings. MPRA Paper No. 1628, posted 2. February 2007

Henderson, R., Jaffe, A., & Trajtenberg, M. (2005) Patent citations and the geography of knowledge spillovers: A reassessment: Comment. American Economic Review, 461-464.

Hughes, S. S. (2001) Making dollars out of DNA: the first major patent in biotechnology and the commercialization of molecular biology, 1974-1980. Isis, 541-575.

Jaffe, A. B. (1986) Technological opportunity and spillovers of R&D: evidence from firms' patents, profits and market value. The American Economic Review, 76, 5, 984-1001.

Jaffe, A. B. (1989) Real effects of academic research. The American Economic Review, 79, 5, 957-970.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations. The Quarterly Journal of Economics, 108, 3, 577-598.

Jørgensen, M.; Phillips, L. (2002) Discourse Analysis as Theory and Method. SAGE London, Thousand Oaks, New Delhi.

Judy, J. W. (2001) Micro electromechanical systems (MEMS): fabrication, design and applications. Smart materials and Structures, 10, 6, 1115.

Klevorick, A. K., Levin, R. C., Nelson, R. R., & Winter, S. G. (1995) On the sources and significance of interindustry differences in technological opportunities. Research Policy, 24, 2, 185-205.

Kresge, N., Simoni, R. D., & Hill, R. L. (2005) The most highly cited paper in publishing history: Protein determination by Oliver H. Lowry. Journal of Biological Chemistry, 280, 28, e25.

Krugman, P. (1991) Geography and trade. Cambridge:MIT Press.

Li, Y. A. (2014) Borders and Distance in Knowledge Spillovers: Dying over Time or Dying with Age?-Evidence from Patent Citations. European Economic Review, 71, 152-172.

Lissoni, F., Llerena, P., McKelvey, M., Sanditov, B. (2008) Academic patenting in Europe: new evidence from the KEINS database. Research Evaluation, 17, 2, 87–102.

Lubik, S., Garnsey, E., Minshall, T., & Platts, K. (2013) Value creation from the innovation environment: partnership strategies in university spin-outs. R&D Management, 43, 2, 136-150.

Marion, T. J., Dunlap, D. R., & Friar, J. H. (2012) The university entrepreneur: a census and survey of attributes and outcomes. R&D Management, 42, 5, 401-419.

Maurseth, P. B., & Verspagen, B. (2002) Knowledge spillovers in Europe: a patent citations analysis. The Scandinavian Journal of Economics, 104, 4, 531-545.

Meyer-Krahmer, F. & Schmoch, U. (1998) Science-based technologies: university-industry interactions in four fields. Research Policy, 27, 835-51.

Mowery, D.C. & Ziedonis, A. A. (2002) Academic patent quality and quantity before and after the Bayh–Dole act in the United States. Research Policy, 31, 399–418.

Narin, F. (1994) Patent bibliometrics. Scientometrics, 30, 1, 147-155.

Nelson, R. R. (2001) Observations on the post-Bayh-Dole rise of patenting at American universities. The Journal of Technology Transfer, 26, 1, 13-19.

OECD (2000) Science, Technology and Industry Outlook 2000, OECD Publishing. doi: 10.1787/sti_outlook-2000-en

O'Shea, R. P., Allen, T. J., Morse, K. P., O'Gorman, C. & Roche, F. (2007) Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience. R&D Management, 37, 1, 1-16.

Pries, F. & Guild, P. (2007) Commercial exploitation of new technologies arising from university research: start- ups and markets for technology. R&D Management, 37, 4, 319–333.

Rappert, B., Webster, A. & Charles, D. (1999) Making sense of diversity and reluctance: academic-industrial relations and intellectual property. Research Policy, 28, 873-890.

Reimers, N. J., & Hughes, S. S. (1998) Stanford's Office of Technology Licensing and the Cohen/Boyer Cloning Patents. Regional Oral History Office, The Bancroft Library, University of California.

Romero de Pablos, A. (2011) Regulation and the circulation of knowledge: Penicillin patents in Spain. Dynamics, 31, 2, 363-383.

Rothaermel, F. T., & Thursby, M. (2005) University–incubator firm knowledge flows: assessing their impact on incubator firm performance. Research Policy, 34, 3, 305-320.

Shibata, T. (2012) Unveiling the successful process of technological transition: a case study of Matsushita Electric. R&D Management, 42, 4, 358-376.

Strauss, A., & Corbin, J. (1990) Basics of qualitative research, grounded theory procedures and techniques. New York: Sage Publications.

Thompson, P. (2006) Patent citations and the geography of knowledge spillovers: evidence from inventor-and examiner-added citations. The Review of Economics and Statistics, 88, 2, 383-388.

Trimmer, W. (Ed.). (1996) Micromechanics and MEMS: Classic and Seminal Papers to 1990. New York: IEEE.

Varga, A. (2000) Local Academic Knowledge Transfers and the Concentration of Economic Activity. Journal of Regional Science, 40, 2, 289–309.

Yin, R. K. (2003) Case Study Research: Design and Methods. California: SAGE Pub.

Zucker, L.G., Darby, M. R. & Armstrong, J. (1998) Geographically localized knowledge: Spillovers or markets? Economic Inquiry, 36, 65-86.

**Figure 1.** Contribution of university patents can be in any of these four quadrants

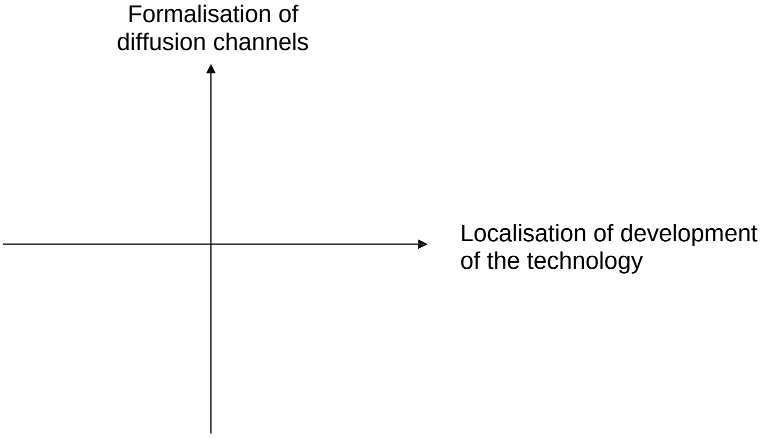



**Figure 2**. Evolution of forward citations to US503346 patent

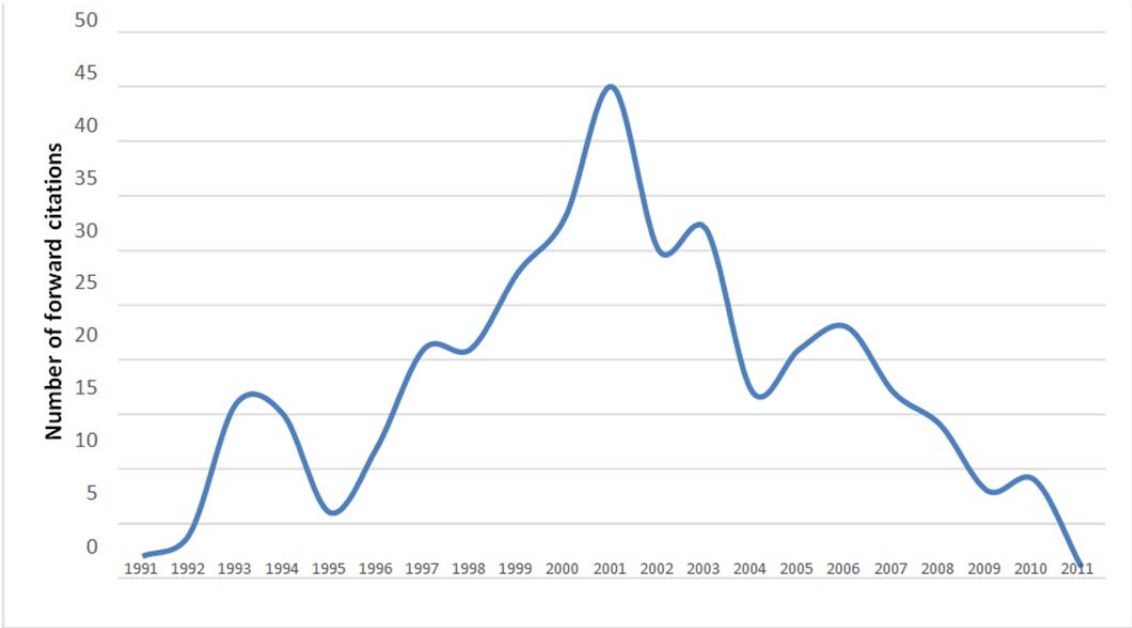


**Figure 3.** Regional and non-regional forward citations to US503346 patent

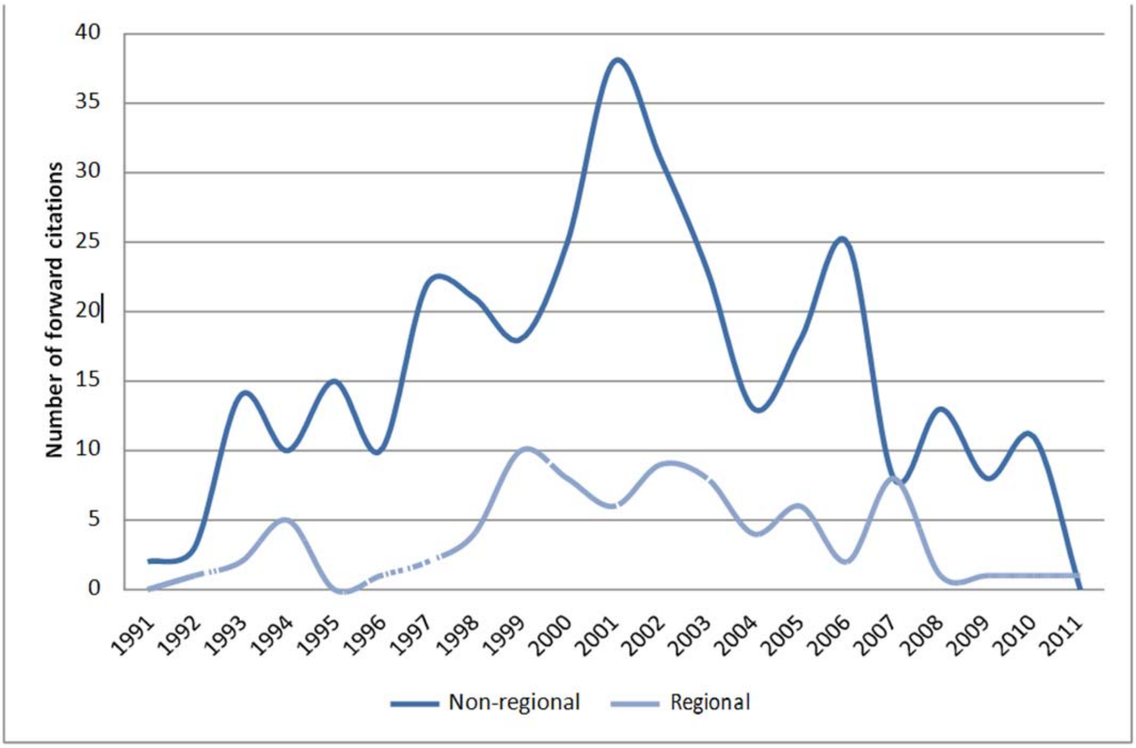



**Figure 4.** Diffusion channels linked to US503346 patent, according to their degree of formalisation and localization

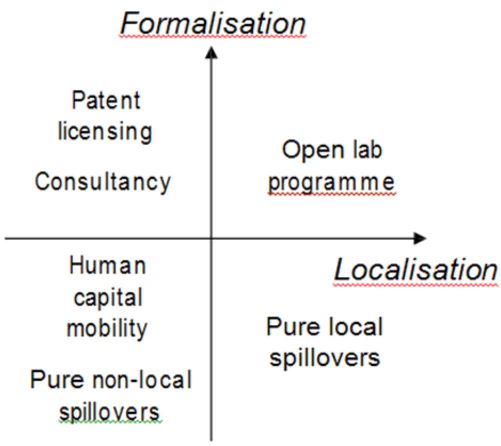
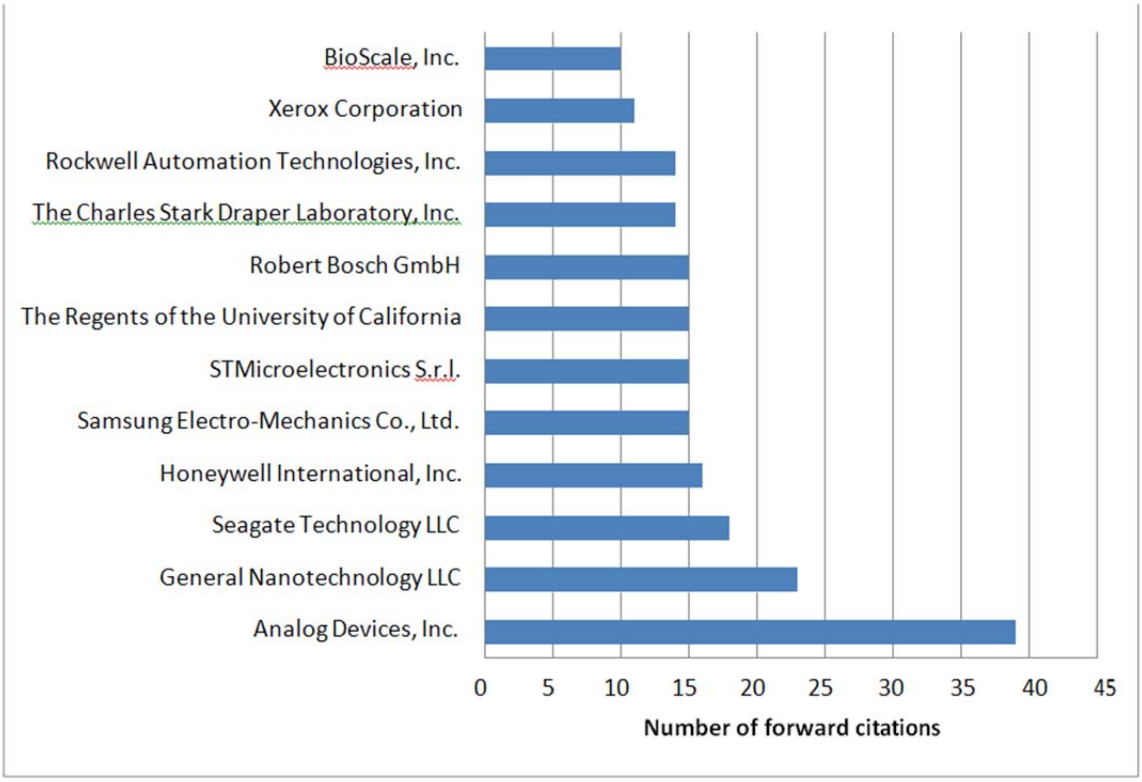


**Figure 5.** Top applicants citing US503346 patent, 1991-2011




Total citations = 375, duplicated if more than one applicant per patent (full count=439).

**Figure 6.** A comparison of knowledge transfer to industry in two cases related with the focal patent

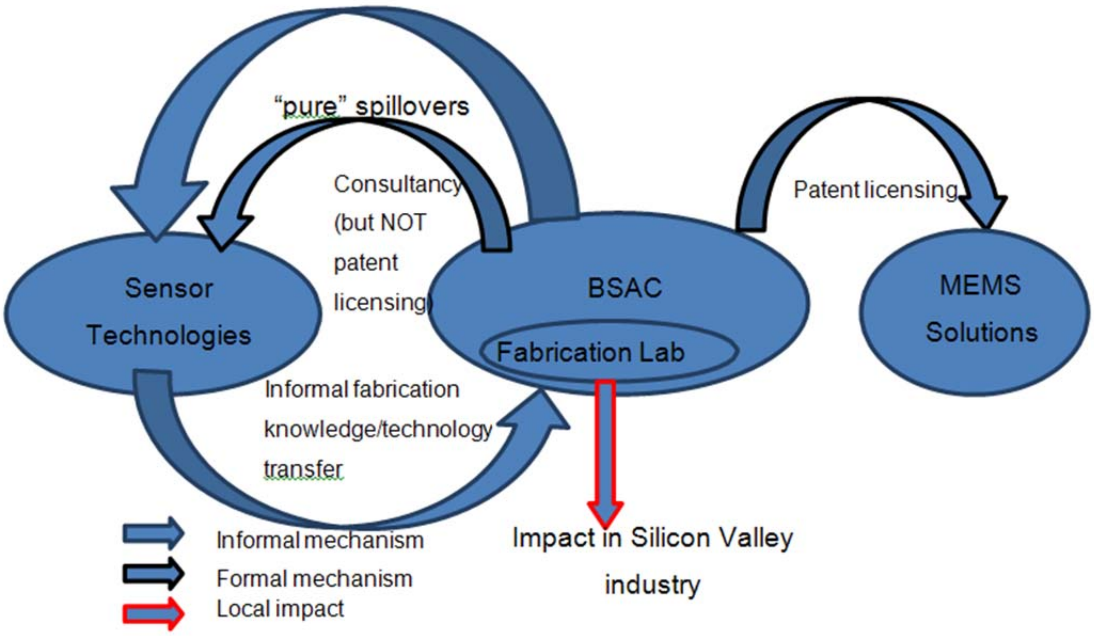


**Table 1.** Identifying highly cited university patents

| Publication number | Applicant | Citing documents (IPTS database) | Citing documents (Espacenet 30/04/2013) |
|---|---|---|---|
| DE19544207 | Univ Dresden Tech [DE] | 8 | 60 |
| EP0601812 | Univ Bristol [GB] | 10 | 12 |
| GB2104391 | Univ Exeter [GB] | 8 | 28 |
| US4618861 | Cornell Res Foundation Inc [US] | 9 | 68 |
| **US5025346** | **Univ California [US]** | **10** | **430** |
| US5177685 | Massachusetts Inst Technology [US] | 9 | 342 |
| US5262871 | Univ Rutgers [US] | 8 | 429 |
| US5561054 | Univ Michigan State [US] | 12 | 33 |
| US5764190 | Univ Hong Kong Science & Techn [HK] | 14 | 109 |
| US5770645 | Univ Duke [US] | 8 | 88 |
| US5799055 | Univ Northwestern [US] | 9 | 110 |
| US6737447 | Univ Akron [US] | 8 | 37 |
| WO9428139 | Massachusetts Inst Technology [US] | 29 | 74 |

**Table 2.** MEMS evolution previous to US5025346 patent (1940s)

Development of pure semiconductors (Ge and Si) and radar during World War II.

(1947) Invention of the point-contact transistor and beginning of the semiconductor circuit industry.

(1949) Improvement of semiconductor transistors performance (grow pure single-crystal silicon), but their cost and reliability was still not completely satisfactory

(1959) Professor Feynman gave his famous lecture ‘There is plenty of room at the bottom’, describing the enormous amount of space available on the microscale: ‘The entire encyclopedia could be written on the head of a pin’.

(1960) Invention of the planar batch-fabrication process, allowing the integration of multiple semiconductor devices onto a single piece of silicon (i.e., monolithic integration).

(1960) Beginning of the IC industry.

(1964) Invention of the metal–oxide–semiconductor field-effect transistor (MOSFET) & complex circuits.

(1970) The resonant gate transistor was the first engineered batch-fabricated MEMS device.

(1970/80) Development of the microprocessor.

(1982) MEMS commercialization was started by several companies that produced parts for the automotive industry

(1983) Kurt Petersen’s seminal paper titled ‘Silicon as a mechanical material’, increasing the awareness of the possibilities that MEMS has to offer

(1984) Feynman lecture titled ‘Infinitesimal machinery’.

**(1989) William C. Tang and Roger T. Howe patented ‘Laterally driven resonant microstructures’ (US 5025346 A, published on 18 June 1991)**

(1989) Howe and Muller at the University of California, Berkeley (UCB) developed the polysilicon surface micromachining process and used it to produce MEMS products with integrated circuits Researchers at UCB and MIT independently developed the first electrostatically controlled micromotors that used rotating bearing surfaces

(1989) Microhinges developed at UCB by Pister et al. extended the surface micromachined polysilicon process so that large structures could be assembled out of the plane of the substrate, finally giving MEMS significant access to the third dimension.

(1990s onwards) A tremendous increase in the number of devices, technologies, and applications (has greatly

Source: adapted from Judy (2001).

**Table 3.** Sensor Technologies and Inventor 2

| Applicant | Inventor 2 self-citations | Others' citations | Total |
|---|---|---|---|
| Sensor Technologies | 5 | 34 | 39 |
| University of California | 9 | 14 | 23 |
| Total | 14 | 48 | 62 |

**Table 4.** National and international forward citations to focal patent

| Applicant world zone | Number of forward citations | % |
|---|---|---|
| International | 164 | 37,4% |
| US, not California | 164 | 37,4% |
| California | 80 | 18,2% |
| US, unknown region | 31 | 7,1% |
| Total | 439 | 100,0% |

**Table 5.** Examiner versus applicant citations

| Applicant world zone | % examiner | % applicant | Total |
|---|---|---|---|
| International | 73% | 27% | 100% |
| US, not California | 43% | 57% | 100% |
| California | 33% | 68% | 100% |
| Total | 54% | 46% | 100% |