Globalization and growth of US university patenting (2009-2014)

Article · August 2016

DOI: 10.1177/0950422216660253

3 authors, including:

Loet Leydesdorff
University of Amsterdam

Duncan Kushnir
Chalmers University of Technology

Globalization and Growth of U.S. University Patenting (2009-2014)

Loet Leydesdorff,*[a] Henry Etzkowitz,[b] and Duncan Kushnir[c]

Abstract

Following a pause, with a relatively flat rate, from 1998 to 2008, the long-term trend of university patenting rising as a share of all patenting has resumed, driven by the internationalization of academic entrepreneurship and the persistence of US university technology transfer. We disaggregate this recent growth in university patenting at the US Patent and Trademark Organization (USPTO) in terms of nations and patent classes. Foreign patenting in the US has almost doubled during the period 2009-2014, mainly due to patenting by universities in Taiwan, Korea, China, and Japan. These nations compete with the US in terms of patent portfolios, whereas most European countries—with the exception of the UK—have more specific portfolios, mainly in the bio-medical fields. In the case of China, Tsinghua University holds 63% of the university patents in USPTO, followed by King Fahd University with 55.2% of the national portfolio.

Keywords: university patents, Bayh-Dole Act, nations, IPC, CPC, USPTO

[a] University of Amsterdam, Amsterdam School of Communication Research (ASCoR), PO Box 15793, 1001 NG Amsterdam, The Netherlands; loet@leydesdorff.net ; *corresponding author
[b] Department of Management, Birkbeck, University of London, London WC1E 7HX, UK; h.etzko@googlemail.com
[c] Environmental Systems Analysis, Chalmers University of Technology, Göteborg, Sweden; duncan.kushnir@chalmers.se

1. Introduction

University patenting originated in the U.S.A. from the need to protect public health and safety and the university's reputation by controlling the manufacture of drugs and food-related products invented by its staff (e.g., insulin, milk purity analysis devices; Apple, 1989; Bliss, 1982). That income could be generated from licensing patents to manufacturers was an ancillary consequence realized by only a few professors and their universities. Some, like the University of Wisconsin, soon made it a feature of their academic policy, providing a model for later legislation (Etzkowitz, 2015).

In addition to assuring ethical quality control, another source of origin of university technology transfer, was gaining control of external "free riders," entrepreneurs who were accessing inventions made at MIT without recompense. The university expressed its pecuniary interest in capitalizing knowledge on behalf of the university and its inventors in the early 20th century, A new academic function and role was created at the intersection of science and business that soon moved beyond protection of intellectual property into an explicit role for the university in creating "new products" and enterprises (Etzkowitz, 2002). A transition, still underway globally, from an industrial to a knowledge-based economy, with the university in a key role, has since produced a series of academic entrepreneurial exemplars.

The balance between social and economic motivations shapes US university technology transfer to this day. After decades of emphasizing economic outcomes in its metrics, the Association of University Technology Transfer (AUTM) recalibrated its emphasis on invention disclosures numbers, patents and royalty income, a strategy that was gaining its members a reputation as “money grubbing’ universities. AUTM inaugurated the so-called “Better World Project,” collecting instances of broader social benefits that it publicizes on its website and makes available for analysis in a publicly available data-base (WiIlbanks in Etzkowitz, Zhou and Tijssen, 2016). Technology transfer has been transformed from a marginal/peripheral to an acknowledged/legitimated academic activity, in part, due to passage of a law, derived from US technology transfer experience that has been transferred globally, sometimes as a narrow legalistic framework but more often as an entrepreneurial academic design.

The Bayh-Dole Regime: Emergence and Efflorescence

The Bayh-Dole Act of 1980 changed the game for university patenting in the US by granting ownership of inventions to universities (and other organizations conducting government-funded research). Prior to the enactment of Bayh-Dole, the US government had accumulated 28,000 patents, but fewer than 5% of these patents were commercially licensed (US General Accounting Office, 1998: 3, at https://en.wikipedia.org/wiki/Bay-Dole_Act ; cf. Berman, 2008; Etzkowitz & Stevens, 1995). The share of patents in the US won by universities grew exponentially for more than two decades (1976-1998; see also Mowery *et al*., 2001; Nelson, 2001; Sampat, 2006). The Bayh-Dole Act was also imitated by other nations as a potential means to bring university research closer to relevant markets (Callaert *et al*., 2013; cf. Rasmussen *et al*., 2006). Some European countries, however, allow professors to file patents themselves (Dornbusch *et al*., 2012).

In the decade 1998-2008 university patenting entered a period of relative decline. Leydesdorff & Meyer (2010) discussed this as "the end of the Bayh-Dole effect" in the US; but Etzkowitz (2013) warned that the academic analysis of university patenting can suffer from excluding contexts and focusing exclusively on numbers of patents and rates of revenue, potentially ignoring subtler impacts of non-patented and unpatentable academic knowledge and its entrepreneurs. Feldman and Clayton (2016) attributed the downturn of university patenting to the global economic recession. However, the period of relative decline in the US antedates the recession, and the recession does not by itself explain the new growth trend in the share of university patenting since 2008. Which factors are driving this new growth?

In recent decades, patents have become more common as an alternative publication outlet for university staff (e.g., Wallmark, 1997). One can consider university patenting also as a sign of the entrepreneurial transformation of universities (Gibbons *et al*., 1994; Slaughter & Rhoades, 2004); but numbers of patents have not yet been appreciated in major rankings of universities such as the ARWU (Shanghai) or Leiden Rankings.[1] Patenting is expensive,[2] so one can assume that a university, academic scholars, or technology transfer officers must have strong reasons to take the commercial risk of filing for a patent (e.g., Breschi *et al*., 2005; Göktepe-Hulten & Mahagaonkar, 2010; Owen-Smith & Powell, 2001). The reasons for university patenting extend well beyond financial motives (Baldini, 2010; Etzkowitz and Göktepe, 2015).

[1] The Academic Rankings of World Universities (ARWU) for 2015 can be found at http://www.shanghairanking.com/ ; the Leiden Rankings of top-universities of the Center for Science and Technology Studies at http://www.leidenranking.com/ .

[2] More recently, US law allows a preliminary application to be filed at little cost while commercial potential is explored.

The economic effects of academic patents are difficult to specify. Mazzoleni (2006), for example, raised the question of whether "open access" may be a more efficient instrument for dissemination. Economic activity emanating from academic sources, through a variety of formal and informal modalities, whether based on intellectual property, classic literature or new business models, utilizing textbook knowledge, create humanities towns as well as silicon anodynes (Etzkowitz, 2014). Academic patenting can also be considered as a result of institutional incentives. Leydesdorff & Meyer (2013, p. 932, Fig. 5) argue that TTOs have been more successful in filing patents as institutional output than in obtaining patents granted at USPTO. However, TTOs often perform a variety of research and regional development functions that may enhance the rate of future applications and also contribute to a penumbra of economic and social development activities. Stevens *et al*. (2016: 139; 143), for example, provide indicative data on firm growth and tax revenues, e.g., 50 billion dollars of the value of the Amgen firm traceable to public sector research, generating 143 billion dollars of private-sector wealth. These authors estimate that five billion dollars in tax impact has derived from 850 million dollars of university royalty income (Swiggart, 2003).

Nonetheless, most universities do not earn from patenting (Geuna & Nesta, 2006). A few universities, like Stanford and NYU, have gained considerably from successful patents. Some universities have lost money by entering this market; others have made huge profits, but typically on a relatively small proportion in a portfolio in which other applications could not succeed at commercialization (Breznitz & Etzkowitz, 2016). Recently (December 9, 2015), Boston University (BU) won a court case about a patent for research contributing to the invention of blue LEDs by Theodore Moustakas (USPTO Patent nr. 5,686,738; Nov. 11, 1997).

BU was awarded US$13 million for the infringement of these intellectual property rights by three Taiwan-based companies.

Patents remain indicators of invention, situated at the very beginning of a pipeline that is still far from market introduction and innovation, let alone revenue and profit. The environment can be considered as "hyper-selective" with the odds against newcomers to the market (e.g., Bruckner *et al*., 1994; Dosi, 1982). A plethora of measures have been proposed and implemented—e.g., translational research funds at the university (MIT, Deshpande; UC San Diego, the Von Liebig Centre), at the state level (California Stem Cell Initiative), and at the national level (NIH)—to move the process forward along the innovation process through an "assisted linear model" of innovation (Etzkowitz, 2006), including incubators, accelerators, and regional innovation policies. However, universities often do not patent, but leave the patenting to an industrial partner in compensation for other benefits or ongoing research collaborations. In many cases, the scientific inventors and/or the industrial collaboration partners including start-ups appear as assignees. As noted, in some countries faculty can file for patents in their own name.

From an innovation-systems perspective, patenting, and university patenting in particular, can perhaps be considered as early indicators of change. Patent classes have been used as indicators of technological relatedness of emerging industries in metropolitan areas (Boschma *et al*., 2014). Furthermore, patents at USPTO have been considered as more competitive for emerging markets than patents filed with other national or regional patent offices (Criscuolo, 2004; Jaffe & Trajtenburg, 2002; Narin & Olivastro, 1992). Note that concepts such as "national innovation systems" (Freeman, 1987; Lundvall, 1988) and "the knowledge-based economy" (David &

Foray, 1995) emerged much later in (e.g., OECD) policy documents than the introduction of the Bayh-Dole Act in 1980 (Godin, 2006).

After "the end of the Bayh-Dole effect"

After a long period of exponential growth in university patenting in the US (1976-1998), the decade 1998-2008 can be considered as a period of relative decline. As noted, the period of relative decline antedates the recession, and the recession does not by itself explain the growth since 2008. Figure 1 analyzes the three periods in terms of their best-fit lines: an exponential upswing until the late 90s, a decline between 1998 and 2008, and resumed linear growth thereafter.

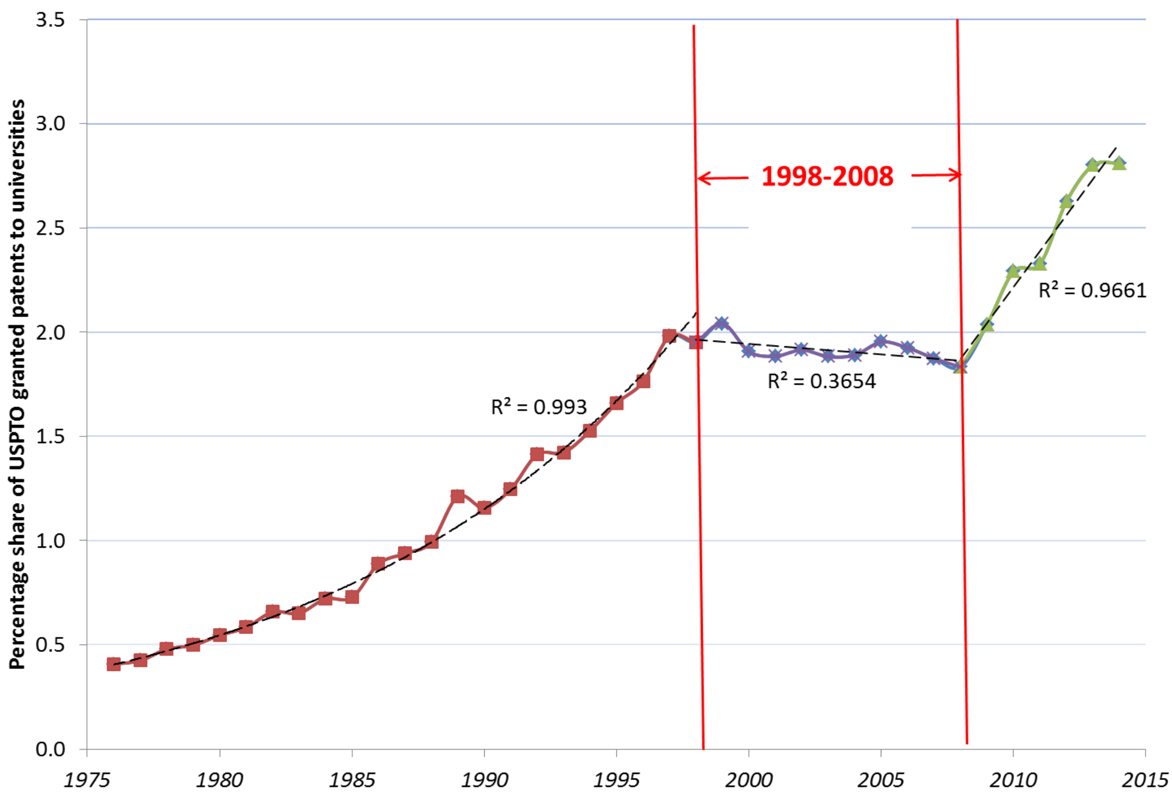

Figure 1: Long-term trends of the percentage share of USPTO patents granted to universities and institutes of technology.

Whereas the exponential growth in the first period may be indicative for an endogenous self-reinforcing development—presumably triggered by the Bayh-Dole Act (Mowery *et al*., 2001; Sampat, 2006; cf. Kenney & Patton, 2009)—linear growth is more likely the result of an external driver. What may be the independent variables of this upward trend? Leydesdorff & Meyer (2013) suggested that patenting by non-US universities at USPTO could be one of the sources of the upswing.

In order to answer this question in greater detail, we decompose the numbers for the latter period in terms of nations and International Patent Classifications (IPC). International Patent Classifications provide a fine-grained index system of patents worldwide that is now further developed in collaboration between USPTO and the European Patent Organization (EPO) into the system of Cooperative Patent Classifications (CPC).[3] The system is elaborated to the level of 14 digits; but we use the 129 classes at the 3-digit level and the 670 classes at the 4-digit level—that are similar between IPC and CPC—as (however imperfect) indicators of the substantive dimension. In the geographical dimension, the analysis is pursued at the level of nations: which nations are capturing a hold in these high-tech markets by means of university patenting, and in terms of which technologies? Can the patterns inform us about competitive edges and emerging university-industry relations (Petruzelli, 2011)? The national portfolios in terms of patent classes

[3] IPC was replaced with the Cooperative Patent Classification by USPTO and the European Patent Organization (EPO) on January 1, 2013. CPC contains new categories classified under "Y" that span different sections of the IPC in order to indicate new technological developments (Scheu *et al*., 2006; Veefkind *et al*., 2012).

can be decomposed further in terms of lower-level geographical units or specific universities, *mutatis mutandis* (see Leydesdorff, Heimeriks, & Rotolo, 2015).

2. Data and Methods

USPTO data was batch-downloaded by one of us as a complete set for the period 1976-2014 from Google on October 2, 2015. This set contains 4,965,279 patents ranging from 70,194 patents granted in 1976 to 301,643 in 2014. The analysis is restricted to so-called "utility" or technical patents; design patents and genetic sequences were excluded, and reissued patents are only counted once. This data set is therefore approximately 10% smaller than that obtained by searching online for a given year, with design patents accounting for most of the difference.

The number of total patents exhibits linear growth during the entire period 1976-2008 ($r^2 > 0.90$) with an increase (β) of approximately 4,700 patents per year. After 2008, the growth accelerates to more than 25,000 patents granted per year ($r^2 > 0.96$). The increase of university patenting during most of this period is thus part of a general trend, but was reinforced to an exponential trend during the period 1975-1998. The linear trend in university patenting since 2008 is based on an increase of approximately 1,000 patents/year (that is, an increase of 0.16% in the share of USPTO total per year).

We use granted patent dates because using filing dates would make our results unreliable for the last few years. The search string used in each consecutive year is 'AN/University OR AN/"Institute of Technology" OR AN/universite OR AN/universitat OR AN/ecole OR

AN/universiteit'.[4] The abbreviation "AN" stands for "assignee name" in USPTO. The data for the period 2009-2014 is organized in terms of the 62 nations holding university patents in the database, and both 129 IPC categories at the three-digit level and 670 IPC-4 digit classes. Of these classes, 108 and 385, respectively, were used as assignments to university patents. IPC classes were cross-tabled with the national addresses, so that strength and growth can be indicated for each nation with the different granularities of IPC-3 and IPC-4. As noted, nations can be decomposed into lower-level units like cities by using, for example, the zip-codes in the address field.

3. Results

3.1. US versus non-US

Are the recent increases in university patenting due to foreign patenting in the U.S.A.? The Japanese government, for example, heavily subsidizes and rewards patenting by university staff, but in Japan university patenting has nevertheless stagnated at the national level (Nishimura, 2011). Furthermore, one would expect increases of Chinese patenting in the database in recent years, due to the rapid expansion of the Chinese economy and academic entrepreneurship during the period under study.

[4] The diacritical characters in "école" and "universität" cannot be included online. This search string can be further extended with names in other languages such as "universidad" in Spanish. We return to this issue in the discussion section.

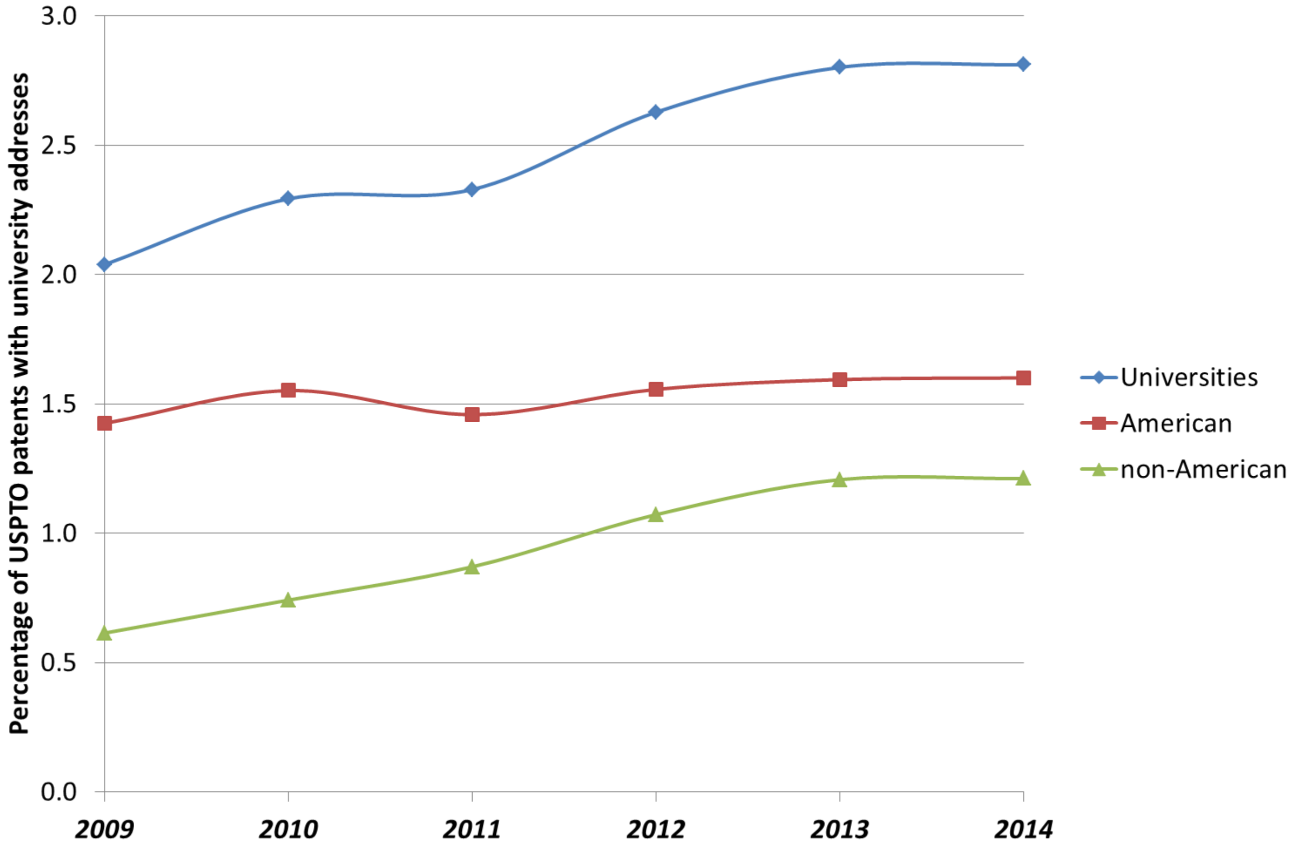

Figure 2: US versus non-US university patenting with USPTO. (Data is based on whole-number counting.)

Figure 2 shows the numbers of patents granted to US and non-US universities as percentages of the database. Whereas the numbers tend to stabilize for American universities at an aggregate of almost 1.6%, the proportions of patents granted to non-US universities has doubled during these five years (from 0.6% in 2009 to 1.2% in 2014). (Note that because of the whole-number counting, co-assignments between US and non-US universities are counted as full points in both segments.) As a percentage of the aggregate of patents with university addresses, the American share has declined during these years from 70.1% to 57.5%, while in the overall database the American share is more or less stable (approximately 45%). In sum, the growth is largely due to foreign patenting.

Table 1: Countries with growth rates in university patenting larger than the USA; 2009 = 100.

Country	*Volume in 2014 given 2009 = 100*	*N of university patents in 2014*
Saudi Arabia	1,788	143
Norway	1,300	13
India	1,200	48
South Africa	850	17
Korea, Republic of	459	500
Denmark	457	32
Belgium	429	90
China	381	362
Japan	355	720
France	352	236
Taiwan, Province of China	350	888
Ireland	344	31
Israel	247	126
Switzerland	220	55
United Kingdom	218	181
The Netherlands	207	29
Canada	198	192
United States	191	5218

Table 1 lists the countries with growth rates in the number of patents granted to universities greater than that of the USA during the period 2009-2014. Although the growth rate of Saudi Arabia is spectacular, the numbers are relatively small, ranging from eight in 2009 to 143 in 2014. The large players and rapid growers, however, are the Asian countries: Taiwan, Korea, Japan, and China. France, Israel, the UK, and Canada are medium-size players, and the other European countries follow with modest contributions ($n < 100$). India, Norway, and South Africa are rapid growers, but modestly sized. Note that Latin American countries are not on this list. Brazil, for example, holds only 13 university patents granted in 2014; Mexico nine; and Argentina only a single one.[5]

[5] These results include the additional terms "universidade" or "universidad" in the online searches.

3.2. Patent classes

Figure 3 and Table 2 show the decomposition of the growth in terms of 4-digit patent classes assigned to university patents (in USPTO) between 2009 and 2014.

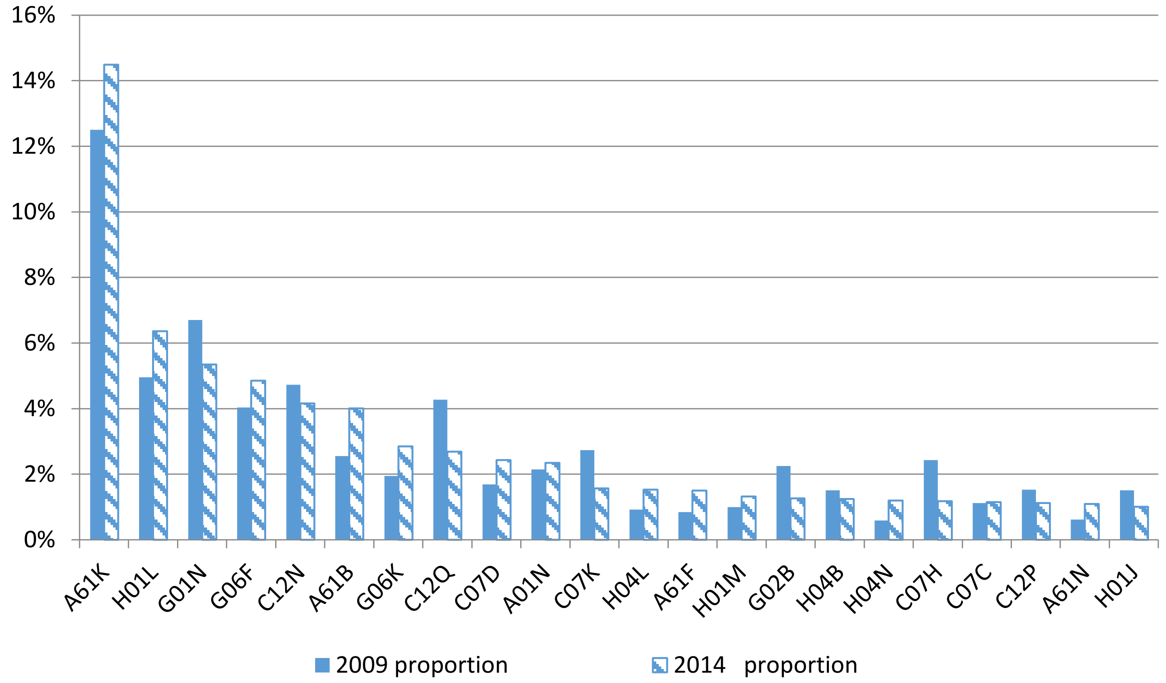

Figure 3: Twenty three patent classes that contributed more than 1% to university patenting at USPTO in 2014.

Table 2: Top ten classifications at the 4-digit level of IPC used in university patenting 2014.

CPC-4 digits	*Definition (shortened)*	*N* (2014)	*Proportional change 2009-214*
A61K	preparations for medical, dental, or toilet purposes	1328	+16%
H01L	semiconductor devices; electric solid state devices not otherwise provided for	583	+28%
G01N	investigating or analysing materials by determining their chemical or physical properties	490	-20%
G06F	electric digital data processing	445	+20%
C12N	micro-organisms or enzymes; compositions thereof	381	-12%
A61B	diagnosis; surgery; identification	367	+57%
G06K	recognition of data; presentation of data; record carriers; handling record carriers	261	+47%
C12Q	measuring or testing processes involving enzymes or micro-organisms	246	-37%
C07D	heterocyclic compounds	223	+44%
A01N	preservation of bodies of humans or animals or plants or parts thereof	215	+9%

The changes between 2009 and 2014 (in the right-most column of Table 2) are in tens of percentages. Are these relatively large changes indicative of flexible—perhaps even opportunistic—shifts of agendas and orientations at research fronts? As noted, IPC classes inform us as proxies about the domains in which university-industry relations can be expected (Boschma *et al*., 2014; Hall & Bagchi-Sen, 2002). Within the longer-term development of these institutional relations, the cognitive classification represents the explorative agents of change (Etzkowitz, 2002; Leydesdorff, 2007; Wallmark, 1997).

3.3. Which nations are increasing their presence in which IPC classes?

The two main dimensions of the set—the institutional one analyzed here in terms of nations and the substantive one that we try to capture with IPC classes—can also be cross-tabled. This matrix contains a wealth of information:

1. The distributions of patent classes over nations in the data can be overlaid on Google maps using, for example, the software made available at http://www.leydesdorff.net/software/patentmaps/ (Leydesdorff & Bornmann, 2012; Leydesdorff, Alkemade, Heimeriks, & Hoekstra, 2015).
2. The distributions of nations over IPC classes can be overlaid on the IPC-based maps developed by Leydesdorff, Kushnir, & Rafols (2014), available at http://www.leydesdorff.net/ipcmaps/ .

Figure 4 shows the network of 28 nations versus 69 IPC codes at the three-digit level that forms the (k = 3) core group in the 2014 set.[6,7]

[6] Eight nodes that are not connected, 44 connected with a single link, and 21 with two links were removed in order to keep the figure readable.
[7] We use the program NetDraw which is particularly suited for visualizing asymmetrical (two-mode) networks (Borgatti, 2002). NetDraw is freely available at https://sites.google.com/site/netdrawsoftware/home.

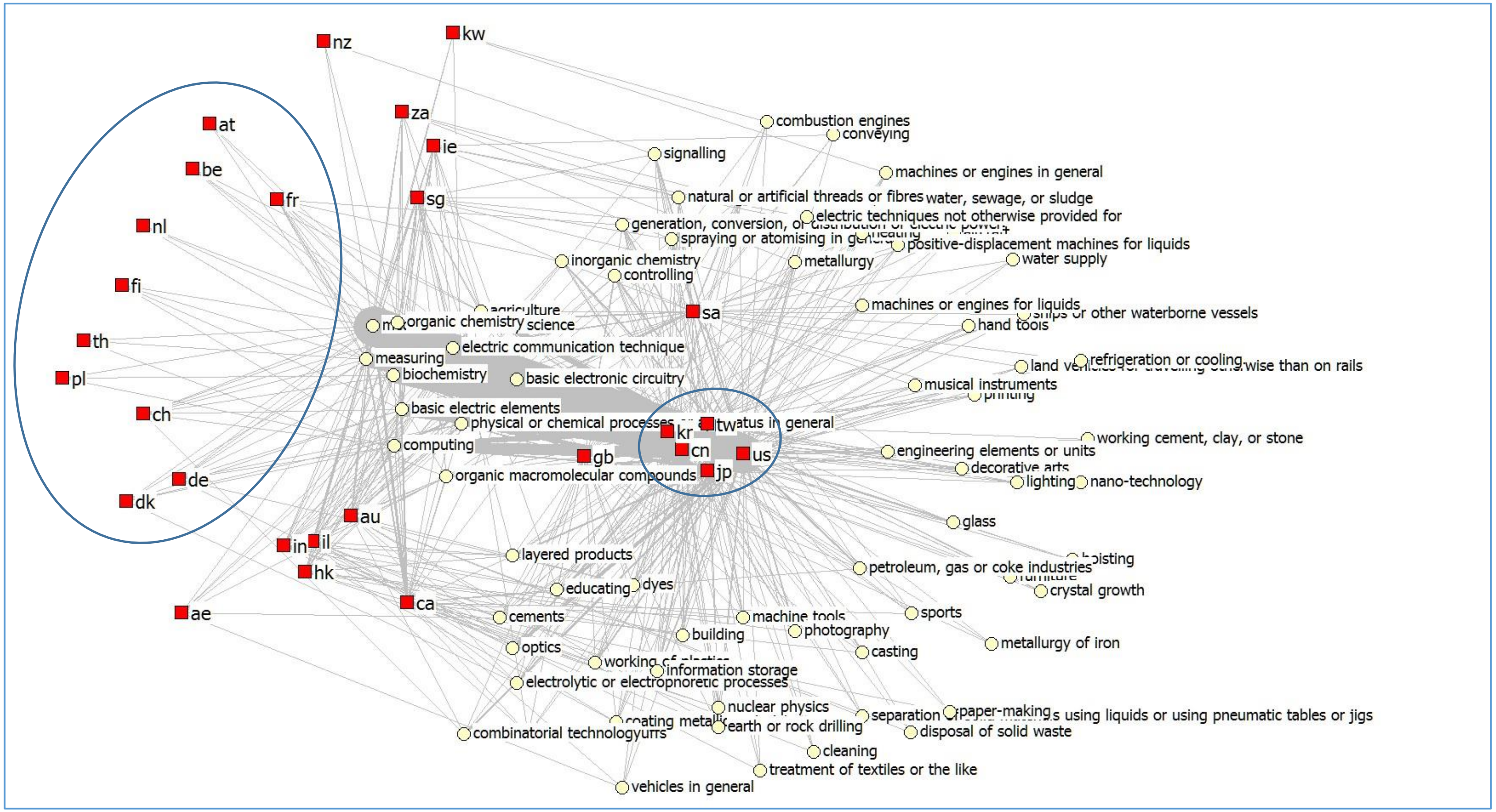

Figure 4: Twenty eight countries and 69 IPC 3-digit categories form the (k = 3) core set of university patenting. (USPTO, 2014).

Figure 4 shows that universities in the Asian countries (Japan, China, Korea, and Taiwan) have a pattern of patenting similar to US universities, whereas European universities (with the exception of Great Britain) share relations to specific patent categories with the U.S.A. The UK assumes an in-between position. (As noted, the number of patents from Saudi Arabia [SA] with a university address is very small.)

Table 3: Most frequently present IPC-4 category in national portfolios of university patenting.

Country	*Top category IPC 4-digits 2014*	
Saudi Arabia	electric digital data processing	G06F
Norway	diagnosis; surgery; identification	A61B
	preparations for medical, dental, or toilet purposes	A61K
India	recognition of data; presentation of data; record carriers; handling record carriers	G06K
South Africa	preparations for medical, dental, or toilet purposes	A61K
Belgium	preservation of bodies of humans or animals or plants or parts thereof	A01N
Korea, Republic of	electric digital data processing	G06F
China	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Japan	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Taiwan, Province of China	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Ireland	preparations for medical, dental, or toilet purposes	A61K
France	preparations for medical, dental, or toilet purposes	A61K
Denmark	processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy	H01M
Israel	preparations for medical, dental, or toilet purposes	A61K
Switzerland	preparations for medical, dental, or toilet purposes	A61K
United Kingdom	preparations for medical, dental, or toilet purposes	A61K
The Netherlands	micro-organisms or enzymes; compositions thereof	C12N
	preparations for medical, dental, or toilet purposes	A61K
Canada	preparations for medical, dental, or toilet purposes	A61K
United States	preparations for medical, dental, or toilet purposes	A61K

In Table 3, the IPC-4 classes with relatively the most patents are provided for the same countries as listed in Table 2 above. Universities in most western nations on this list focus on patenting in the bio-medical arena; but Denmark is mainly patenting in energy conversion given its industrial focus on alternative sources of energy. American universities share the focus on the bio-medical category with other Western countries, but as noted above, the *pattern* of patenting at the national level is more akin to that of the four leading Asian nations. The focus is here on electronic devices.

Table 4: Leading universities in national portfolios 2014.

Country	*Top-university*	*N*	*national share*
Saudi Arabia	King Fahd University of Petroleum and Minerals	79	55.2%
Norway	Universitetet i Oslo	5	35.7%
India	Indian Institute of Technology Bombay	11	22.9%
South Africa	University of Cape Town	5	29.4%
Korea	Industry-Academic Cooperation Foundation, Yonsei University	24	4.8%
Denmark	Technical University of Denmark	8	25.0%
Belgium	Universiteit Gent	12	13.3%
China	Tsinghua University	228	63.0%
Japan	Kyoto University	37	5.1%
France	Université Pierre et Marie Curie, Paris 6	7	3.0%
Taiwan	National Tsing Hua University	113	12.7%
Ireland	Dublin City University	8	25.8%
Israel	Yissum Research Development Company of the Hebrew University of Jerusalem	11	8.7%
Switzerland	Ecole Polytechnique Féderale de Lausanne	18	32.7%
United Kingdom	University of Birmingham	10	5.5%
The Netherlands	Technische Universiteit Delft	9	20.9%
Canada	University of British Columbia	29	15.1%
United States	Regents of the University of California	448	8.6%

Table 4 shows the universities leading in these 18 countries in terms of numbers of patents. The patent portfolios are highly skewed in the case of China, where 63% of the university patents are held by Tsinghua University. The King Fahd University follows with 55.2%.

4. Conclusions and discussion

After a decade of relative stagnation (1998-2008), university patenting in USPTO has increased linearly since 2009, rising from approximately 2% to 3% of all annual patents. We have demonstrated that this growth is driven by foreign universities that maintain patent portfolios in theUS The four major players are Taiwan, Korea, China, and Japan, but some smaller players have also begun to patent at USPTO, for example, the King Fahd University in Saudi Arabia. These patents of new entrants and fast growers are mostly concentrated in electronics, whereas a group of moderately growing, mostly European countries patent mainly in the bio-medical sectors.

Our retrievals underestimate the numbers of patents granted to universities, but we do not expect these trends to be different if one adds other possible variants to the search string. The initial extension of the search string from only English words to other languages (French, German, Dutch) did not change the trends significantly. Similarly, the use of online or the batch results are slightly different, with most of the effect from including design patterns or not. But also in this case, the trends expressed in percentages remain robustly the same. As noted, academic patenting demarcates a larger set than university patenting because patenting is sometimes left to the industrial partner, startups, or incubators; and in some countries to members of the faculty themselves (Dornbusch *et al*., 2012)..

From the perspective of universities, patenting is just another indicator of output. On the input side, university patenting is driven by contextual factors, including faculty mind-set, university entrepreneurial culture or resistance against that model, research funding levels and other university income, TTO capabilities (in finding licensees and/or encouraging start-ups), and general economic conditions (Rasmussen *et al*., 2006). Patenting is one element in a much broader regime of academic innovation and entrepreneurship (Richards, 2009). As Mitra and Edmonson (2014: 472) formulate: "Patenting represents one way on which universities have become cognizant of their role as exemplary knowledge producers in terms of both public service and the commercialization of such knowledge."[11] Since the economic expectations of academic entrepreneurship remain high, the emerging propensity of non-US universities to patent in the US can be expected to increase further as part of the broader transformation of universities to an entrepreneurial mode in which they play a more significant role in economic and social developments, both on their own initiative and incentivized by national, regional, and multinational actors (OECD, 2012).

References

Apple, R. (1989). Patenting university research. Harry Steenbock and the Wisconsin Alumni Research Foundation. *ISIS, 80*(303), 375.

Baldini, N. (2010). Do royalties really foster university patenting activity? An answer from Italy. *Technovation, 30*(2), 109-116.

Berman, E. P. (2008). Why did universities start patenting? Institution-building and the road to the Bayh-Dole Act. *Social studies of science, 38*(6), 835-871.

Bliss, M. (1982). *The Discovery of Insulin*. Chicago: Chicago University Press.

Borgatti, S. P. (2002). *NetDraw Software for Network Visualization*. Lexington, KY: Analytic Technologies.

Boschma, R., Balland, P.-A., & Kogler, D. F. (2014). Relatedness and technological change in cities: the rise and fall of technological knowledge in US metropolitan areas from 1981 to 2010. *Industrial and Corporate Change, 24*(1), 223-250.

Breschi, S., Lissoni, F., & Montobbio, F. (2005). From publishing to patenting: Do productive scientists turn into academic inventors? *Revue d'économie industrielle, 110*(1), 75-102.

[11] Stevens *et al*. (2016) even argue that "the social act of transferring technology to industry far outweighs the profit earned from such activities." Such a broad socio-innovation framework ("Better World") is now being developed by the Association of University Technology Managers (AUTM) alongside the survey metrics in the Statistics Access for Tech Transfer (STATT) database.

Breznitz, S. M., & Etzkowitz, H. (Eds.). (2016). *University Technology Transfer: The Globalization of Academic Innovation*. London, etc.: Routledge, Studies in Global Competition.

Bruckner, E., Ebeling, W., Montaño, M. A. J., & Scharnhorst, A. (1994). Hyperselection and Innovation Described by a Stochastic Model of Technological Evolution. In L. Leydesdorff & P. Van den Besselaar (Eds.), *Evolutionary Economics and Chaos Theory: New Directions in Technology Studies* (pp. 79-90). London: Pinter.

Callaert, J., Du Plessis, M., Van Looy, B., & Debackere, K. (2013). The impact of academic technology: do modes of involvement matter? The Flemish case. *Industry and innovation, 20*(5), 456-472.

Criscuolo, P. (2004). *R&D Internationalisation and Knowledge Transfer*. Unpublished Ph.D. Thesis, University of Maastricht, Maastricht: MERIT.

David, P., & Foray, D. (1995). Assessing and Expanding the Science and Technology Knowledge Base. *STI Review, 16*, 13-68.

Dornbusch, F., Schmoch, U., Schulze, N., & Bethke, N. (2012). Identification of university-based patents: A new large-scale approach. *Research Evaluation, 22*(1), 52-63.

Dosi, G. (1982). Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change. *Research Policy, 11*(3), 147-162.

Etzkowitz, H. (2002). *MIT and the Rise of Entrepreneurial Science*. London: Routledge.

Etzkowitz, H. (2006) The new visible hand: an assisted linear model of science and innovation policy *Science and Public Policy 33*(5), 310-320.

Etzkowitz, H. (2013). Mistaking dawn for dusk: quantophrenia and the cult of numerology in technology transfer analysis. *Scientometrics, 97*(3), 913-925.

Etzkowitz, H. (2014) Making a humanities town: knowledge-infused clusters, civic entrepreneurship and civil society in local innovation systems *Triple Helix Journal*

Etzkowitz, H. (2015) The Evolution of Technology Transfer. In S. M. Breznitz & H. Etzkowitz (Eds.), *University Technology Transfer: The globalization of academic innovation* (pp. 3-22). London: Routledge

Etzkowitz, H. (2016) The Entrepreneurial University: Vision and Metrics *Industry and Higher Education*, May.

Etzkowitz, H., & Stevens, A. J. (1995). Inching toward industrial policy: the university's role in government initiatives to assist small, innovative companies in the United States. *Science Studies, 8*(2), 13-31.

Feldman, M., & Clayton, P. (2016). The American Experience in University Technology Transfer. In S. M. Breznitz & H. Etzkowitz (Eds.), *University Technology Transfer: The globalization of academic innovation* (pp. 37-65). London: Routledge.

Freeman, C. (1987). *Technology and Economic Performance: Lessons from Japan*. London: Pinter.

Geuna, A., & Nesta, L. J. (2006). University patenting and its effects on academic research: The emerging European evidence. *Research Policy, 35*(6), 790-807.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: the dynamics of science and research in contemporary societies*. London: Sage.

Godin, B. (2006). The Knowledge-Based Economy: Conceptual Framework or Buzzword? *Journal of Technology Transfer, 31*(1), 17-30.

Göktepe-Hulten, D., & Mahagaonkar, P. (2010). Inventing and patenting activities of scientists: in the expectation of money or reputation? *The Journal of Technology Transfer, 35*(4), 401-423.
Hall, L. A., & Bagchi-Sen, S. (2002). A study of R&D, innovation, and business performance in the Canadian biotechnology industry. *Technovation, 22*(4), 231-244.
Kenney, M., & Patton, D. (2009). Reconsidering the Bayh-Dole Act and the current university invention ownership model. *Research Policy, 38*(9), 1407-1422.
Leydesdorff, L. (2007). Scientific Communication and Cognitive Codification: Social Systems Theory and the Sociology of Scientific Knowledge. *European Journal of Social Theory, 10*(3), 375-388.
Leydesdorff, L., & Bornmann, L. (2012). Mapping (USPTO) Patent Data using Overlays to Google Maps. *Journal of the American Society for Information Science and Technology, 63*(7), 1442-1458.
Leydesdorff, L., Heimeriks, G., & Rotolo, D. (2015; Early view). Journal Portfolio Analysis for Countries, Cities, and Organizations: Maps and Comparisons. *Journal of the Association for Information Science and Technology*. doi: 10.1002/asi.23551
Leydesdorff, L., & Meyer, M. (2010). The Decline of University Patenting and the End of the Bayh-Dole Effect. *Scientometrics, 83*(2), 355-362.
Leydesdorff, L., & Meyer, M. (2013). A Reply to Etzkowitz' Comments to Leydesdorff & Martin (2010): Technology Transfer and the End of the Bayh-Dole Effect. *Scientometrics, 97*(3), 927-934. doi: 10.1007/s11192-013-0997-5
Leydesdorff, L., Alkemade, F., Heimeriks, G., & Hoekstra, R. (2015). Patents as instruments for exploring innovation dynamics: geographic and technological perspectives on "photovoltaic cells". *Scientometrics, 102*(1), 629-651. doi: 10.1007/s11192-014-1447-8
Leydesdorff, L., Kushnir, D., & Rafols, I. (2014). Interactive Overlay Maps for US Patent (USPTO) Data Based on International Patent Classifications (IPC). *Scientometrics, 98*(3), 1583-1599. doi: 10.1007/s11192-012-0923-2
Lundvall, B.-Å. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg & L. Soete (Eds.), *Technical Change and Economic Theory* (pp. 349-369). London: Pinter.
Mazzoleni, R. (2006). The effects of university patenting and licensing on downstream R&D investment and social welfare. *The Journal of Technology Transfer, 31*(4), 431-441.
Mitra, J., & Edmondson, J. (2015). From past to future: where next? In J. Mitra & J. Edmondson (Eds.), *Entrepreneurship and Knowledge Exchange* (pp. 468-488). London: Routledge.
Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2001). The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980. *Research Policy, 30*(1), 99-119.
Narin, F., & Olivastro, D. (1992). Status Report: Linkage beteen technology and science. *Research Policy, 21*, 237-249.
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.
Nishimura, Y. (2011). Recent trends of technology transfers and business-academia collaborations in Japanese universities. *Journal of Industry-Academia-Government Collaboration, 7*(1), 13-16.
OECD (2012) *A Guiding Framework for Entrepreneurial Universities*. Paris: OECD.

Owen-Smith, J., & Powell, W. W. (2001). To patent or not: Faculty decisions and institutional success at technology transfer. *The Journal of Technology Transfer, 26*(1-2), 99-114.

Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation, 31*(7), 309-319.

Rasmussen, E., Moen, Ø., & Gulbrandsen, M. (2006). Initiatives to promote commercialization of university knowledge. *Technovation, 26*(4), 518-533.

Richards, G. (2009). *Spin-Outs: Creating Businesses from University Intellectual Property*. Hampshire: Harriman House Limited.

Sampat, B. N. (2006). Patenting and US academic research in the 20th century: The world before and after Bayh-Dole. *Research Policy,* 35(6), 772-789.

Scheu, M., Veefkind, V., Verbandt, Y., Galan, E. M., Absalom, R., & Förster, W. (2006). Mapping nanotechnology patents: The EPO approach. *World Patent Information, 28*, 204-211.

Slaughter, S., & Rhoades, G. (2004). *Academic Capitalism and the New Economy: Markets, State, and Higher Education*. Baltimore, MD: Johns Hopkins University Press.

Stevens, A. J., Jensen, J. J., Wyller, K., Kilgore, P. C., London, E., Chatterjee, S. K., & Rohrbaugh, M. L. (2016). The Commercialization of New Drugs and Vaccines Discovered in Public Sector Research. In S. M. Breznitz & H. Etzkowitz (Eds.), *University Technology Transfer: The Globalization of Academic Innovation* (pp. 102-146). London: Routledge.

Swiggart, W.(2003) The Bayh-Dole Act & the State of University Technology Transfer in 2003. At www.swiggartagin.com/articles/Bayh_Dole_act.doc, retrieved on Nov. 29, 2015.

Veefkind, V., Hurtado-Albir, J., Angelucci, S., Karachalios, K., & Thumm, N. (2012). A new EPO classification scheme for climate change mitigation technologies. *World Patent Information, 34*(2), 106-111.

Wallmark, J. T. (1997). Inventions and patents at universities: the case of Chalmers University of Technology. *Technovation, 17*(3), 127-139.

Willbanks, R.In Etzkowitz, H, C Zhou and R Tijsson, (2016). Global Entrepreneurial University Metrics: Science, Innovation and Entrepreneurship Washington DC US National Science Foundation, SciSip Program (proposal under review)

Table 1: Countries with growth rates in university patenting larger than the USA; 2009 = 100.

Country	*Volume in 2014 given 2009 = 100*	*N of university patents in 2014*
Saudi Arabia	1,788	143
Norway	1,300	13
India	1,200	48
South Africa	850	17
Korea, Republic of	459	500
Denmark	457	32
Belgium	429	90
China	381	362
Japan	355	720
France	352	236
Taiwan, Province of China	350	888
Ireland	344	31
Israel	247	126
Switzerland	220	55
United Kingdom	218	181
The Netherlands	207	29
Canada	198	192
United States	191	5218

Table 2: Top ten classifications at the 4-digit level of IPC used in university patenting 2014.

CPC-4 digits	*Definition (shortened)*	*N* (2014)	*Proportional change 2009-214*
A61K	preparations for medical, dental, or toilet purposes	1328	+16%
H01L	semiconductor devices; electric solid state devices not otherwise provided for	583	+28%
G01N	investigating or analysing materials by determining their chemical or physical properties	490	-20%
G06F	electric digital data processing	445	+20%
C12N	micro-organisms or enzymes; compositions thereof	381	-12%
A61B	diagnosis; surgery; identification	367	+57%
G06K	recognition of data; presentation of data; record carriers; handling record carriers	261	+47%
C12Q	measuring or testing processes involving enzymes or micro-organisms	246	-37%
C07D	heterocyclic compounds	223	+44%
A01N	preservation of bodies of humans or animals or plants or parts thereof	215	+9%

Table 3: Most frequently present IPC-4 category in national portfolios of university patenting.

Country	*Top category IPC 4-digits 2014*	
Saudi Arabia	electric digital data processing	G06F
Norway	diagnosis; surgery; identification	A61B
	preparations for medical, dental, or toilet purposes	A61K
India	recognition of data; presentation of data; record carriers; handling record carriers	G06K
South Africa	preparations for medical, dental, or toilet purposes	A61K
Belgium	preservation of bodies of humans or animals or plants or parts thereof	A01N
Korea, Republic of	electric digital data processing	G06F
China	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Japan	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Taiwan, Province of China	semiconductor devices; electric solid state devices not otherwise provided for	H01L
Ireland	preparations for medical, dental, or toilet purposes	A61K
France	preparations for medical, dental, or toilet purposes	A61K
Denmark	processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy	H01M
Israel	preparations for medical, dental, or toilet purposes	A61K
Switzerland	preparations for medical, dental, or toilet purposes	A61K
United Kingdom	preparations for medical, dental, or toilet purposes	A61K
The Netherlands	micro-organisms or enzymes; compositions thereof	C12N
	preparations for medical, dental, or toilet purposes	A61K
Canada	preparations for medical, dental, or toilet purposes	A61K
United States	preparations for medical, dental, or toilet purposes	A61K

Table 4: Leading universities in national portfolios 2014.

Country	*Top-university*	*N*	*national share*
Saudi Arabia	King Fahd University of Petroleum and Minerals	79	55.2%
Norway	Universitetet i Oslo	5	35.7%
India	Indian Institute of Technology Bombay	11	22.9%
South Africa	University of Cape Town	5	29.4%
Korea	Industry-Academic Cooperation Foundation, Yonsei University	24	4.8%
Denmark	Technical University of Denmark	8	25.0%
Belgium	Universiteit Gent	12	13.3%
China	Tsinghua University	228	63.0%
Japan	Kyoto University	37	5.1%
France	Université Pierre et Marie Curie, Paris 6	7	3.0%
Taiwan	National Tsing Hua University	113	12.7%
Ireland	Dublin City University	8	25.8%
Israel	Yissum Research Development Company of the Hebrew University of Jerusalem	11	8.7%
Switzerland	Ecole Polytechnique Féderale de Lausanne	18	32.7%
United Kingdom	University of Birmingham	10	5.5%
The Netherlands	Technische Universiteit Delft	9	20.9%
Canada	University of British Columbia	29	15.1%
United States	Regents of the University of California	448	8.6%