R&D Funding in US Universities: From Public to Private Support or Public Policies Strengthening Diversification?

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1. Introduction

Most research and development in industrialised countries today is funded by private sources. This clearly shows that we live in knowledge-based economies; firms set out to accumulate knowledge and produce new ideas to improve their performance in increasingly global and competitive markets. Economic incentives are increasingly designed to reward skills, creativity, and innovation; with high valued-added activities linked with producing ideas rather than things. There is an 'innovation race' in which firms invest in R&D because they fear that other firms will take over their market with a new process or product if they don't keep up. Private dynamics are increasingly dominating OECD S&T systems, accounting for more than 63% of R&D funding in OECD countries in 2001 (OECD 2003a). Though increasingly widespread in developed and developing countries, this dynamic is particularly strong in the United States, which has one of the highest business expenditures on R&D of all OECD countries.

The United States innovation system relies heavily on a high level of private R&D funding and performance, but also on a set of private incentives and available venture capital funds, usually allocated to high-technology sectors. The success of the United States economy, together with the apparent sustainability of its R&D and innovation system fuelled by private funds and sets of incentives, is attractive to many policy makers from less developed countries. However, as Conceição et al. (2004) demonstrated, replicating US policy in different national and economic contexts may not only be misguided, but even ineffective and possibly harmful. Given the path dependence of the science, technology, and innovation systems, and despite perceptions and what one might be inclined to conclude from the above discussion, actual US policies to promote innovation and to support science and technology are more complex than a mere swing of the pendulum from public to private incentives. Conceição et al.'s analysis shows that the US has been able to shift from public to private incentive structures because of its long history of channelling significant public funds to science and technology. This enabled the accumulation of knowledge through massive investment in basic research and constructing infrastructure that could then be used by the private sector. Furthermore, despite the extensive and intensive use in recent decades of intellectual property rights and other market-based incentive structures, public support for core areas and those fields for which there is a perception that market incentives are not sufficient to meet the strategic targets of the US policy, has not been compromised; indeed, it has been reinforced.

It is necessary to understand the diversity of its policies and mixture of public and private incentives if the US S&T system is to be taken as a reference. Moreover, its long history of past investments and the current division of labour (specialisation) cannot be replicated in systems of lesser scale and complexity. The key elements of the US story are those of diversity of policies and increasing institutional specialisation and of the clarification of the unique roles of private and public incentives to support S&T.

Just as the US S&T system as a whole is taken as a worldwide reference, the US university system is also used as a role model for its responsiveness to economic changes and contribution to wealth creation (Hall 2007). Recently, there is a clear understanding, mainly by European counterparts (EC 2003), that the universities are generally viewed as important engines of economic growth and development rather than mere institutions of higher education (Saxenian 1994), as there is increasing evidence of their importance as promoters of regional industrial and technological development (Cooke and Huggins 1997). This is a role that US universities, especially research universities, have assumed throughout the second half of the 20th century. Here too, as with the whole US S&T system, there is the perception that private funding associated with a high level of industry-science relationships is plentiful and encourages a highly dynamic academia that contributes much more directly and with greater impact to social and economic development at both regional and national levels. In this context, the possibility of obtaining funding from private sources and private incentives (such as IPRs) makes itself highly appealing for European universities struggling with increasing financial difficulties arising from public budget constraints and demands for change and closer engagement with society.

This paper argues that transforming the European university landscape into the image of its American counterpart is not feasible because of wide differences in history and different sets of incentives and institutional frameworks. Even so, some lessons can be learned from analysing the US higher education sector and its R&D function. Another important objective of this paper is to contribute to a better understanding of the reality of the US university landscape, beyond superficial notions popularised by the media, interest groups, and even some policy analysts. First, we confirm that public financing continues to be the largest source of funding of US universities for R&D by far, and that this financing is more critical for universities than for the rest of the US S&T system. It is then shown that expenditure per researcher in the whole system is balanced between public (universities, Federal laboratories) and private institutions (business sector), while in Europe there is an imbalance towards the private sector. We also show that in the US science and technology system the university is gaining importance as an R&D performer. We conclude that most US R&D funding is heavily concentrated in the top one hundred universities, but that the US higher education system is extremely diversified, with various revenue sources, unlike the selected European research universities. Furthermore, we identify two trends: 1) the US higher education system's diversity is maintained by a range of federal R&D funding agencies that allocate funds to narrower or wider sets of universities according to the scientific complexity or goal of their research objectives. Given this situation, the vast majority of universities specialise in R&D for certain agencies' research interests; 2) the share and composition of the groups of universities receiving the largest R&D income has remained reasonably stable over the last 30 years.

To make these points, section 2 discusses the funding evolution patterns of the US S&T system. Section 3 then examines the development of the university system within the US R&D system over the last 50 years. This analysis will focus on the US universities R&D revenue sources, funding concentration, and diversification issues as well as their responsiveness to shifting patterns of economic requirements. This section analysis is concluded by discussing the concentration of R&D funding and universities' revenue sources for select US and European universities. Section 4 briefly presents our conclusions.

2. Our evidence: on the role of private and public R&D funding in the US S&T system

Awareness of the importance and commitment of the university in the innovation process emerged in what Bruland and Mowery (2004) call the third industrial revolution, though links between industry and formal science were first forged during the 19th century in continental Europe (especially in the German chemical industry) and in the United States. The third revolution is an ongoing process that started after 1945, initially in the United States, and then spread globally. It was fostered by Vannevar Bush's Endless Frontier report, which led to the creation of the National Science Foundation (NSF) in 1950. There was unprecedented support for public R&D funding, especially at the federal level, motivated by national defence and public health concerns and political support for basic research. US public support for science and technology was extended with the creation of new agencies such as the National Aeronautics and Space Administration (NASA), and support for research in areas of strategic national interest such as health (through the National Institutes of Health) and energy (through the Department of Energy). However, despite constant shifts defence-related R&D funding as a proportion of total R&D was higher than non-defence related funding for most of the period between 1949 and 2004.[1] During this time, the Department of Defence was (and still is) the agency providing most R&D funds for the entire US S&T system; in 2004 reaching the highest budget in its history (65 billion dollars). Of non-defence related R&D funding since 1997, health-related research, represented mostly by the National Institutes of Health, has accounted for more than 25% of total non-defence research and continues to grow apace (it reached 31% of total non-defence related R&D in 2004). This immense and continuous public investment was only surpassed by private funding in 1979 (NSB 2000), as reliance on private funding gained the necessary strength and sustainability based on the infrastructure created by public funding, IPRs, and public-based incentive mechanisms to grow at a much faster pace than public funding from then onwards.

There has been a steady decline in the ratio of public to private funding since 1979, as the private sector took an increasing share of overall funding for R&D. The private funding of R&D has been increasing at a constant rate, while public spending has decreased (in real terms) from its peak in 1987, remaining stable during the 1990s (NSB 2002). There

1 See AAAS reports I through XXIX, based on OMB and agency R&D budget data.

has been a stagnation of public funding and a swing of the pendulum towards intellectual property-based incentives. However, in cumulative terms, only very recently has public support been surpassed by private funding (Conceição et al. 2004).

The cumulative effect of decades of sustained large-scale public support for science and technology is of great importance because it is a proxy for the effects associated with long-lasting investments in R&D. Knowledge is cumulative in nature. Innovations are built upon basic science and previous innovations, which have had to be supported in the past. Similarly, the cumulative support is reflected in equipment and, much more importantly, institutions such as the modern US research university on which both private and public R&D and people-training depend. Few if any other countries can lay claim to the sustained and large-scale public sector support found in the US. Even if the pendulum is now swinging towards the private, the US in a sense can afford it. Other countries without the history of capacity-building reflected in the US's cumulative public spending may be attempting to stimulate creativity and innovation where no raw materials exist. Despite the swing of the pendulum to the private side, public support for basic research – one of the goals of the Vannevar Bush influential report – continues to increase, sustained mainly by public funding, and leading other sources of funding by a large margin. It can even be argued that public funding is encouraging private spending on basic R&D, though this may be a reflection of the emergence of the biotechnology business sector. The continued funding of basic research is evidence that the US government is investing in its long-term future, using mostly public rather than private incentives.[2] But where do the US universities stand in this process?

3. US universities research funding: sources, responsiveness, concentration, and diversification

To address this question, we discuss the data given above under three major headings: public funding of university research, US universities' responsiveness, and the concentration and diversification of funding sources.

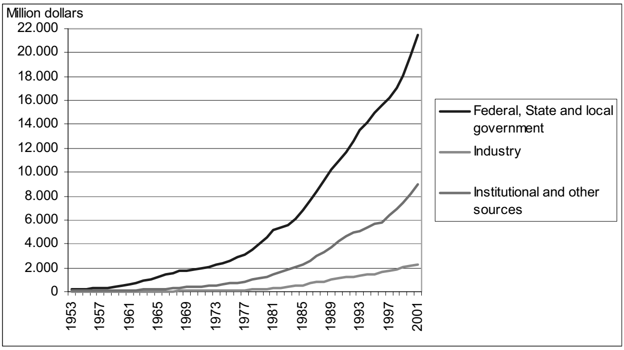
2 For a detailed discussion on this matter see Conceição et al., 2004.

3.1 Public financing and university research

Unlike the European university, the US research university is a very recent creation that emerged as a result of the post-war economic environment, public funding, and shaping by federal government. Since the post-war period, there has been a close link between the development of universities and the development of the R&D system in the United States. A huge amount of mostly federal public funding has poured into university R&D in the form of grants, contracts, and other financing for specific research projects. Universities in the US have increasingly become major performers of R&D, especially basic research. Rosenberg (2002) argues that the idea of the appropriate role of universities to conduct basic research is itself a post-war notion in the US, and thus this type of research is usually financed by public funds. It is therefore not surprising that since the late 1950s academic R&D has been concentrated at the basic research end of the R&D spectrum and strongly supported by federal funding; nowadays considered to be "virtually the only source of support for basic research" (NAE 2003, p. 7).

US universities' R&D performance depends upon federal, state, and local government funding. Public funding accounted for 66% to 83% of total university R&D funding received yearly from 1953 until 2001, as shown in Figure 1. However, the share of federal funding for academic R&D has been declining from 1966 since its peak in the mid-sixties (73%), accounting for about 58% of the total funding allocated to US universities in 2000. State and local funding for targeted academic R&D has fluctuated between 7% and 8% since the 1980s, though its importance for the overall US academic research system is understated in this figure as they also fund universities (especially public ones) through general purpose appropriations used to cover uncompensated indirect costs or to apply in separately budgeted research.

Figure 1: R&D expenditure at US universities and colleges, by source of funds: fiscal years 1953-2001



Note: Fiscal year 1978 data are estimated based on data collected from doctorate-granting institutions only
Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development

Although the private funding of R&D has surpassed public funding in the US science and technology system, US university R&D continues to be overwhelmingly supported by public funds, mainly from the federal government. In this respect, it should be noted that federal R&D funding is allocated through various departments and agencies, unlike in most OECD countries in which public funding is mostly concentrated in a single state structure. Federal agencies cover a wide range of science and engineering fields when they fund academic research.[3] These agencies concentrate or diversify their funding according to their primary goals. For example, the National Institutes of Health tend to concentrate their funding on life and medical sciences, while the National Science Foundation has more diversified funding patterns (NSB 2002). In addition, agencies vary considerably in their funding instruments: the Department of Defence (DOD) and NASA favour funding of extramural R&D activities through contracts; the Department of Health and Human Services (HHS), the United States Department of Agriculture (USDA), and NSF prefer to work through formula or project grants. As a consequence, universities obtaining funds from the latter agencies have a high degree of autonomy in pursuing R&D activities, as federal government control over R&D conducted through grants is limited. Moreover, the federal government usually attaches rights on R&D outcomes under R&D con-

3 There are 24 funding agencies, though 96% of the federal budget transferred to US universities comes from six.

tracts and not under grants, thus enabling the universities to profit from intellectual property rights over federally funded R&D results. According to Fossum et al. (2004), the majority of federal R&D funds transferred to universities are conveyed in the form of project grants. This reinforces the argument that with regard to universities, the US federal S&T funding system is by definition a decentralised archetype "with relatively low top-down control, hardly any institutional funding apart from mission-oriented programs, and a strong research base in universities" (OECD 2003b, p. 41).

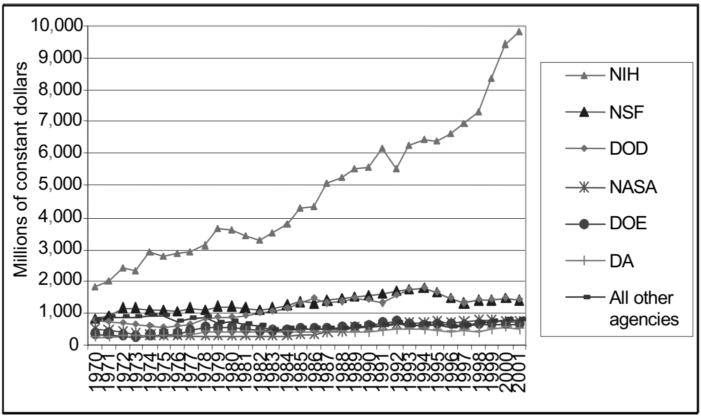
Having distinct missions and goals, the funding agencies request research in the form of competitive grants or contracts for specific research projects in a variety of universities, public and private, which are dependent on federal funding but determined to remain autonomous (Mowery and Rosenberg 1993). As seen in Figure 2, the main provider of obligations for science and engineering to universities and colleges is the Department of Health and Human Services, mostly through the National Institutes of Health. This is unlike non-university components of the S&T system, in which the Department of Defence is by far the largest R&D funder. Between 1970 and 2001, DOD's share of academic R&D funding in US universities was never higher than 17%, which shows that the US university sector is above all performer of non-defence related R&D. Nevertheless, for some universities, such as the Massachusetts Institute of Technology, defence related R&D provided to be essential for the consolidation of R&D activities and its continuous development in this university along the 20th century (Geiger 1993).

According to NSF data[4], more than four-fifths of total obligations for academic R&D derive from three agencies: the Department of Health and Human Services (funding academic R&D mostly through the National Institutes of Health) which accounts for 60%, and the National Science Foundation and the Department of Defence, accounting for 15% and 9% respectively. The growing share of health-related research marks a major change in federal academic research funding by the HHS, as other agencies' share of funding remained the same or decreased slightly between 1970 and 2001. The increase in federal support for health-related research in the 1970s and 1980s was mainly related to cancer and AIDS research (Jankowski 2001). In the 1990s, in addition to cancer and AIDS, this was reinforced by a growing interest in directing research towards other diseases, the opportunities afforded by advances in biotechnology, and the influence of lobbying groups (NSB 2002). However, the increased concentration of funds in the life and medical sci-

4 Withdrawn from the Webcaspar data system.

ences is raising concerns about uneven distribution and its impact on the academic research enterprise.

Figure 2: Federal obligations for academic R&D, by agency: 1970-2001



Notes: Values in constant 1996 dollars. NIH: National Institutes of Health; NSF: National Science Foundation; DOD: Department of Defense; NASA: National Aeronautics and Space Administration; DOE: Department of Energy; DA: Department of Agriculture. Data for the National Institutes of Health include the Alcohol, Drug Abuse, and Mental Health Administration. Data for 1970-73 are for the Atomic Energy Commission; data for 1974-76 are for the Energy Research and Development Administration; data for 1977 and thereafter are for the Department of Energy.

Source: National Science Foundation, Division of Science Resources Studies (NSF/SRS), Federal Funds for Research and Development: Fiscal Years 1999, 2000 and 2001, Detailed Statistical Tables, Vol. 49, NSF 01-328 (Arlington, VA, 2001); and NSF, annual series

The continuing and increased support for university R&D from public funds reinforces the argument presented by Conceição et al. (2004) that the US government continues to support research in core areas of national importance where private funding is insufficient. It also means that the US private sector performs most of the research that it funds, and that it only provides universities with a small fraction of their overall R&D funding capital. In 2000, the industrial sector performed 98% of total industry-funded R&D, while universities and colleges performed 1%.

Despite the long record of research partnerships between industry and universities, funding provided by the private sector did not represent more than 6.8% of total university financed R&D in 2001 (Table 1). Private funding of university R&D was higher in 1955 than it was in 2001, which leads us to argue that the sustainability of the university research sector is strongly based on public funding and public policies, not on private sources. However, several surveys undertaken during the 1990s show that industry accounts for an important share of funding in academic R&D in specific fields, particularly in engineering (Morgan et al. 1994). Close contact with industry is recognised as critical for encouraging rapid and constant technology transfer (NAE 2003). Furthermore, the role of private funding for R&D activities became critical for the development of some research universities in the US, such as the case of Stanford University (Geiger 1993).

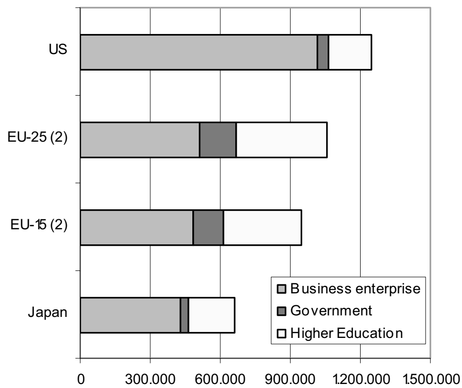
Table 1: Percentage of total university financed R&D and total industry funding for selected fiscal years

	Industry	**Industry funding (millions of dollars)**
1955	8%	25
1960	6.2%	40
1965	2.8%	41
1970	2.6%	61
1975	3.3%	113
1980	3.9%	236
1985	5.8%	560
1990	6.9%	1127
1995	6.7%	1489
2001	6.8%	2234

Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development

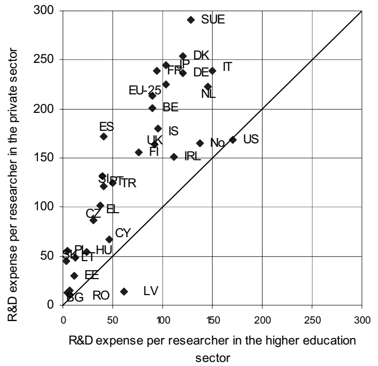
This continuous R&D funding for universities also lets them compete with private sector institutions, thus allowing them to retain top-quality faculty and researchers. This is not the case in European countries, where a smaller private sector can offer much better salaries than the higher education sector. As Figure 3 shows, expenditure per researcher in the private sector in the United States represents 79% of this expenditure in the European Union (25 countries), while the expenditure per researcher in the higher education sector in the European Union (25 countries) is 53% of that in the United States. This clearly shows that US universities are much more competitive in terms of R&D funding per researcher than their European counterparts. It also displays an imbalance in Europe between universities and industry in terms of recruiting the best researchers and providing them with the best equipment and laboratories.

Figure 3: Researchers (FTE) – Total numbers and by performance sector, 2001



Notes: The figure refers to 2001 or the last year available. The sectors do not add up to 100%: AT, UK: 1998; BE, DK, EL, US: 1999; FR, IE, IT, NL, EU-15, EU-25: 2000; (2) EU-15, EU-25 data are estimated by DG RTD and total numbers do not include LU or MT. Data on EU-25 by sector exclude LU, CY, EE, LT, LV and MT. Source: DG Research; Data: OECD, MSTI 2003/Vol. 1, for non-OECD members: Eurostat/Member States; Source: Eurostat, Key Figures 2003-2004

Figure 4: R&D expenditure per researcher in the private sector and in the higher education sector, 2001

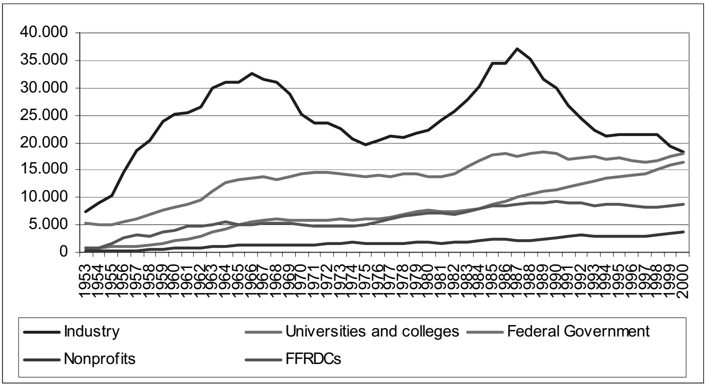


Notes: (B) – The figure refers to 2001 or the last year available: AT, UK: 1998; BE, DK, EL, US: 1999; FR, IE, IT, NL, EU-15, EU-25, TR, CH:2000.
Source: DG Research; Data: OECD, MSTI 2003/Vol. 1, for non-OECD members: Eurostat/Member States; Source: Eurostat, Key Figures 2003-2004

3.2 The responsiveness of US universities

The role of the universities as performers in the US R&D system is well established and their importance as a vital national asset recognised (Popper and Wagner 2002). While federal labs and private industry have historically received most federal funds (private industry with two large peaks in the mid-1960s and the mid-1980s), if current trends continue universities will become the main receivers of public R&D funding in the US (Figure 4). Between 1953 and 2000, academic R&D increased more than fourfold, rising from 0.07 to 0.30 percent of gross domestic product, with a stronger average annual growth in R&D than any other R&D performing sector. The growth of federal funding for universities indicates a strategic aim to use them as critical performers in the R&D system. The government's use of industrial research laboratories to scan university R&D for potential commercial importance is a policy tool to maintain US universities' responsiveness to changing patterns of economic needs and opportunities through transferring knowledge and technology to the private sector.

Figure 5: Evolution of US Federal Public Allocation of R&D



Note: FFRDCs: Federally Funded Research and Development Centers
Source: adapted from US NSB, 2002

As with funding, the responsiveness of universities is associated with the evolution of the US R&D system. This system began to benefit from massive federal investment in military research, some of it conducted in the universities. With the intensification of the cold war the federal government used procurement contracts (mainly associated with military research), a push type of incentive that created a huge demand for high-tech products and enabled high-tech industrial sectors to be developed around universities; especially in electronics, computers, and later on, biotechnology[5] (NAE 2003). Conceição et al. (2004) argue that the growth in non-defence public R&D expenditure has mainly been in health and basic science. As mentioned previously, life sciences account for 58% of the total R&D expenditure allocated by the federal government to US universities.[6] This availability of funds in life sciences ensures a strong motivation for the universities to do research in this area. Consequently, as Rosenberg (2002) points out, universities are investing in the life sciences because they expect high economic and social payoffs to accompany the investment trend of the federal government. As he compares the responsiveness rates of US universities with their European counterparts, Rosenberg states that US universities have learned to respond quicker to the perception of a new set of economic opportunities. This is a major advantage, as Nelson (2004) points out; to a great

5 Through the increase of the National Institutes of Health funding.
6 The life sciences account for $ 11.178.689 of a total of $ 19.190.873 total Federal R&D expenditure for universities and colleges in 2001.

extent, the development of modern science needs to be understood as the result of institutionalised reactions to challenges and opportunities.

This responsiveness may also be linked to the fact that there is no US Higher Education ministry. The US higher education system is decentralised, with universities and colleges competing as if the higher education system were like any other market. Mowery and Rosenberg (1993) argue that linkages between industry and universities in the US have been strongly influenced by this decentralised structure and constant federal funding, mainly for public universities. The fact that universities are not directly controlled or dependent upon a strict set of rules fosters differentiation and forces each university to establish its own governance to compete for research funding, better students, and better faculty. The universities' fund-raising offices and Offices of Technology Licensing are a reflection of the existing decentralised and competitive environment.

A recent misperception, which originated in part as a result of the proliferation of the Offices of Technology Licensing and interest groups promoting their activities, is that licensing revenues and royalties are important sources of university financing. The proliferation of these offices resulted in part from the Bayh-Dole act, which allowed small businesses and universities to license technologies and research results funded by public sources (that is, from the federal government). However, as Table 2 shows, licensing and royalty revenues are typically only a small percentage of total university revenues – just over 0.5% for all US universities. Even for those universities with more income of this type, the figure is perhaps only 10 times as much (that is, around 5%). Furthermore, these revenues tend to be associated with a very small number of licenses, often less than half a dozen, and in many cases are based on a single technology. To be fair, the intent of the Bayh-Dole legislation was not to help universities obtain funding. Rather, it was to promote technology transfer from the lab to the economy – whether the policy is effective in this constitutes an on-going debate beyond the scope of this analysis. The point is that universities' IP-related revenues are minute.

Table 2: Gross Revenues and Patent Licensing Revenues of Selected Universities

	Total revenues ($ million)	**Licensing and royalties ($ million)**	**% of total**
All universities	$ 227,000	$ 1270	0.56%
Columbia University	$ 2,038	$ 193 $ 100-20 (see notes)	9.5% 4.9-5.9%
University of California	$ 8,500	$ 100 $ 75 (net)	1.18% 0.88%
Stanford University	$ 2,400	$ 43 $ 36.6 (see notes)	1.79% 1.52%
Florida State University	$ 2646	$ 36	1.36%
University of Wisconsin – Madison	$ 1696	$ 32	1.89%
University of Minnesota	$ 1135	$ 26.5 (see notes)	2.33%
Harvard (03)	$ 2349	47.9	2.03%
Cal Tech (03)	$ 531	$ 26.7 (see notes)	5.02%

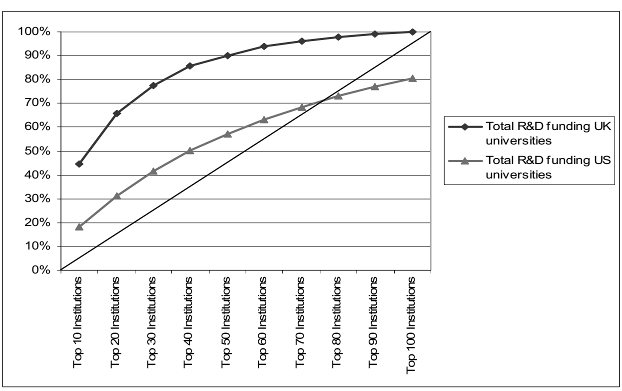
Notes: Columbia University: There is considerable uncertainty because the technology transfer office reports increased revenues for year-end 2003 as $178M without reporting expenses; the University Annual Report reports licensing revenue with all 'revenue from other educational and research activities', and reports a 10% decline in this category, attributed to reduced licensing revenues from the $133M for the previous year-end, 2002. The table reflects an assumed net contribution to university revenues of $100-120M. Stanford University: Minus direct expenses, not including expenses for unlicensed inventions. University Minnesota: University Office of Patents and Technology Marketing, 2002, gross revenues only. Cal Tech: Almost half of this amount is in income from a single initial public offering, and therefore does not represent a recurring source of licensing revenue.
Sources: Aggregate revenues: U.S. Dept. of Education, National Center for Education Statistics, Enrollment in Postsecondary Institutions, Fall 2001, and Financial Statistics, Fiscal Year 2001 (2003), Table F: Association of University Technology Management, Annual Survey Summary, FY 2002 (AUTM 2003), Table S-12. Individual institutions: publicly available annual reports of each university and/or its technology transfer office.

3.3 Concentration and diversification of funding sources

The concentration of R&D funding is an important way to characterise a country's university R&D system. According to the Carnegie Foundation classification, there were 3941 institutions of higher education in the US higher education system in 2000. Of these, only 6.6%, or 261, were considered doctoral/research universities. However, the top research universities correspond to just 3.8% of the total, no more than 110 universities. The United Kingdom university system consists of 171 institutions; most perform R&D.

If we compare these two university systems we can conclude that R&D funding for universities in the US is much more concentrated than in the UK university system, as the total R&D funding for academia in the US goes to about 3% of the universities, while in the UK it is distributed among about 58% of the universities. However, if we analyse only the one hundred institutions with the most R&D income in the US and in the UK, it can be seen that there is a much more even distribution of funds among the one hundred largest R&D income US universities. Thus, there is less differentiation between universities and more even competition for R&D funds in this set of US research universities than in the UK. The confirmation of this is that the top fifty US universities receive 59% of the total R&D funds, while the top fifty UK universities receive 89% (Figure 5).

Figure 6: Distribution of R&D funds for the 100 highest R&D income US and UK universities, 2001



Source: NSF, Academic Research and Development Expenditures, Webcaspar database; HESA, Resources of Higher Education Institutions

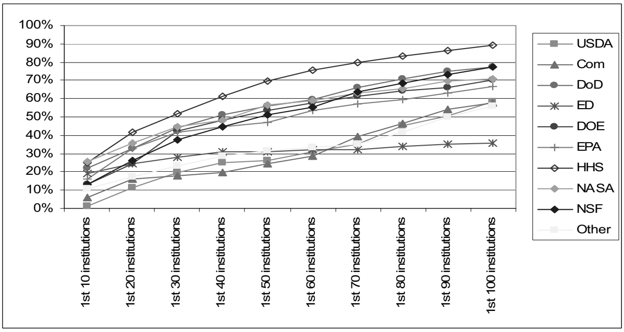
If we deepen the analysis of R&D funding distribution among US universities, we can identify two trends: a specialisation in the distribution of federal funds by the agency towards specific types of universities; and the concentration of R&D funds in the one hundred universities with the highest R&D income has remained relatively stable at least since 1972, in both share of academic R&D funding and group composition, though a decline in the R&D share of the largest ten receivers of R&D was identified confirming previous analyses (Geiger 1999; Geiger and Feller, 1995).

Concerning the first trend, by analysing the distribution of federal research funds by agency to the one hundred US universities receiving the most R&D funds (Figure 6), a process of specialisation in the allocation of funds can be identified. This group of universities, mostly composed of research extensive/intensive universities, received about 80% of total federal funds for R&D in 2000. Thus, Figure 8 shows that the one hundred universities with the most R&D income concentrate the allocation of federal R&D funds in health, engineering, military, and energy-related areas. The concentration on these areas is especially high in the first fifty universities, which account for more than 50% of funds provided by the HHS, DOD, NASA, DOE, and NSF to the overall US higher education system. The fact that 90% of the Health and Human Services Department's R&D budget is allocated to this group of universities is explained by the fact that the university research hospitals are mainly situated at research/doctoral universities, which form the core of the one hundred universities with the greatest federal R&D income. Moreover, in 2002 45% of all federal funds went to medical schools, showing that the presence of a hospital on a university campus strongly affects the amount of federal R&D funding that the university obtains. At the same time, the high degree of complexity of military and engineering research explains why the Department of Defence and the National Science Foundation focus about 80% of their R&D funding on these universities, which have more qualified faculty and researchers, more promising students, and better-equipped laboratories than most other universities in the US higher education system whose mission is more oriented towards teaching and providing research with lower levels of complexity for state or local needs. But as Fossum et al. (2004) concluded, funding allocation specialisation is also a university specialisation, as universities were only able to get significant funds from all major federal R&D agencies in four states[7], if medical R&D funds are excluded. These authors also showed that in most states, universities tend

7 California, New York, Pennsylvania, and Texas.

to specialise in R&D in specific scientific fields, supported by just one or two major federal R&D agencies.

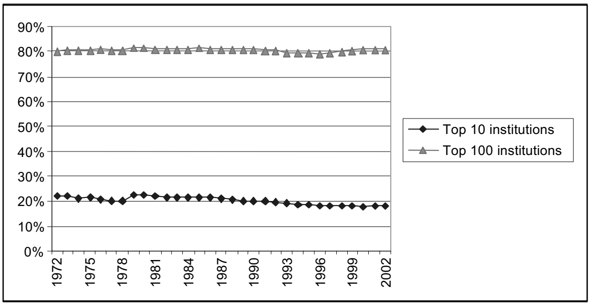
Figure 7: Federal distribution of funds by agency among the 100 universities and colleges receiving the largest amounts, fiscal year 2001



Note: DOD – Department of Defence; HHS – Department of Health and Human Services; NASA – National Aeronautics and Space Administration; DOE – Department of Energy; NSF – National Science Foundation; USDA – Department of Agriculture; EPA – Environmental Protection Agency; Com – Department of Commerce; ED – Department of Education.
Source: National Science Foundation/Division of Science Resources Statistics, Survey of Federal Science and Engineering Support to Universities, Colleges and Non-profit Institutions, fiscal year 2001

The accumulation of and competition for federal funds among the research universities, along with the scarcity of critical resources at their disposal, explains the second trend. Figure 7 shows that the share of academic R&D of universities and colleges by rank of R&D expenditures has remained relatively stable since the early 1970s. Despite a slight decline in the share of funds among the ten institutions receiving the most R&D funding, it can be argued that their share has remained relatively stable during the considered period. The same stability can be observed when considering the historical concentration of academic R&D funds among the 100 universities receiving most R&D funding.

Figure 8: Share of academic R&D of universities by rank of funding among the top 10 and 100 largest receivers of R&D funds



Source: NSF, Academic Research and Development Expenditures, Webcaspar database

More significant than just showing stability in the concentration of academic R&D funds is the composition of both the ten and one hundred largest receivers of academic R&D funding. Based on recent NSF data and considering the 30-year period between 1972 and 2002, we identified only two universities that have remained among the top 10 largest R&D fund receivers throughout, the University of Michigan (comprising all campuses) and the University of Wisconsin (Madison campus). If we only consider the last ten years, the number of universities always present in the top ten rises to four.[8] Apparently, there are constant changes among the top 10 academic R&D funding receivers, as only two universities have kept their place during the last 30 years and 4 during the last 10 years. From 1972 to 2002 however, Stanford and the Massachusetts Institute of Technology were only out of the top ten for three years, Washington University (Seattle campus) and University of Minnesota (all campuses) for five, and John Hopkins University and the University of California (San Diego) for seven. Moreover, since 1972 only universities positioned among the top 23 largest receivers of R&D funds ever reached the top 10, and some remained there for less than 10 years.[9] Analysing the one hundred institutions with the largest share of R&D funds during the same period, 74 universities were always present in this group. In this group of universities, as also found in the top 10 group,

8 University of Michigan, all campuses; University of Wisconsin, Madison; John Hopkins University; and the University of Washington, Seattle (three public and one private universities).

9 Such as Columbia University (New York).

several other universities were within the top 100 for most of the period, only falling out for a few years.

Analysis of the data clearly shows that despite the high competitiveness in the US higher education system, lifting a university into the first 10 or even the first 100 largest receivers of R&D income is a hard task. The issue is that the research university's vital resources are very scarce; from exceptional students, competitive grants, and publication opportunities to high-quality and productive faculty. Using faculty as an example, research universities compete for faculty mostly regarding their research abilities, but candidates with these characteristics are much less predictable or available than teaching-oriented faculty. This scarcity makes the competition very intense. US research universities compete for such particularly R&D-oriented faculty worldwide in the expectation that they will add quality to the university's research; bringing in more research funding and top quality students. In this regard, the ability to mobilise resources to assure the best faculty is critical, and the top research universities have it along with another added value: brand reputation. But difficult internal career upgrading, pressure, and quality standards for scientific production are also critical in maintaining research quality and assuring that the universities at the top continue to receive the most R&D funds. In this respect, Lombardi et al. state that "the advantage in the competition goes to those who have the money today to buy the services of talented people and the equipment and resources needed," adding that "what matters most is the cash generated by these assets and other activities, which the university can immediately spend to compete" (2001, p. 10). Following these authors' views, research universities are seen as quality engines whose goal is the accumulation of the largest amount and the highest level of quality by obtaining scarce elements in a competitive environment, thus making it hard for other universities with less resources to upgrade.

The diversity of the US higher education system can also be seen in the revenue sources (Table 3). The main income source of the major research universities in the US, classified by the Carnegie Foundation as 'doctoral/research-extensive', comes from research revenues. This is especially evident in the case of MIT where research revenues account for almost 54% of the university's total revenue. The difference is striking between doctoral/research-extensive universities (who obtain the lion's share of R&D funding in the US university system and thus have large budgets) and doctoral/research-intensive universities such as Illinois State University or Michigan Technological University. In doctoral/research-intensive universities budgets are much lower and income sources are based more on tuition fees[10] than on research. Master's colleges and universities, usually supported by state and local governments, have the lowest budgets and their incomes are based on tuition fees and government funds. In 1996/97, state and local sources allocated 45% and 89% of their total budgets to higher education institutions such as Master's universities and Baccalaureate and Associate's colleges respectively. For the same year, only 18% of the total federal budget went to these types of universities.[11]

10 Illinois State University also accounts for an important share of government funds.

11 Data from the National Center for Education Statistics

Table 3: Revenue by source for selected universities and colleges in the US (in Million dollars, in %)

	Stanford	**(%)**	**MIT**	**(%)**	**Illinois State University**	**(%)**	**Michigan Technological University**	**(%)**	**Jackson-ville State University**	**(%)**
Research revenues	802	38.2	892.4	53.9	25.8	9.7	19.2	20.5	12.8	16.9
Tuition, student income	305	14.5	167.8	10.1	82.5	30.8	52.8	56.3	28.3	37.2
Investment income, including government funds in public universities	441	21	289.8	17.5	85.3	31.8	0	0	28.3	37.2
Other sources	546	26	308	18.6	74.1	27.7	21.8	23.2	6.5	8.6
TOTAL	2100	100	1658	100	267	100	93	100	76	100

Notes: MIT 2004, Stanford 2002; Illinois State University 2003; Michigan Technological University 2002; Jacksonville State University 2002. According to the Carnegie Foundation classification: Doctoral/Research-Extensive: Stanford, MIT; Doctoral/Research-Intensive: Illinois State University, Michigan Technological University; Master's colleges and universities: Jacksonville State University

Sources: Stanford University Annual Report 2002; MIT Facts 2004; Illinois State University, Fact Book 2003/2004; Michigan Technological University Fact Book 2002/2003; Jacksonville State University Fact Book 2002/2003

However, these two types of institutions have different missions, purposes, and students; additionally, it is known that research universities are supported by a wide range of colleges and universities that by offering education at undergraduate levels provide a large pool of human resources for the research universities' graduate schools and research-related careers. This reveals a dichotomy in the US higher education system between the research university (analysed in this paper) and the teaching university, and shows that the sustainability of research universities depends upon conditions in the teaching universities.

In Europe, the same analysis shows a very similar picture among several selected 'research universities' from different countries (Table 4). All the selected universities depend mainly upon government funds, though the University of Manchester has more diversified revenue sources. A comparative analysis between the two tables reveals that the role of the state as a funding source is of utmost importance for universities. In the US it provides research funding for doctoral/research-extensive universities and government funds for education and research (mainly at state and local level) for other university types; in Europe it is the main income source of all the selected universities. However, it is clear that the European universities are under-funded in comparison with US universities. This is evident not only by the total budgets of European universities compared to doctoral/research-extensive universities in the US, but also by the low expenditure per researcher (as seen in Figure 3).

Table 4: Revenue by source for selected universities in Europe (in Million dollars, in %)

	University of Manchester	(%)	Leiden University	(%)	Trinity College Dublin	(%)	Universidad Autónoma Madrid	(%)	Instituto Superior Técnico	(%)
Research revenues	140.3	23.5	81.8	16.4	47.2	23.2	26	13.2	28.3	24
Tuition, student income	131.1	22	24	4.8	58.1	28.6	24.3	12.3	10.6	9
Government funds	182.7	30.5	328.4	65.8	87.3	43	130.3	66	61.6	52
Other sources	143.7	24	64.9	13	10.6	5.2	16.6	8.4	17.6	15
TOTAL	598	100	499	100	203	100	197.9	100	118.6	100

Note: University of Manchester 2002; Leiden University 2002; Trinity College Dublin 2002; Universidad Autónoma de Madrid 2002; Instituto Superior Técnico 2004.

Sources: HESA, Resources of Higher Education Institutions; Leiden University, Facts and Figures; The University of Dublin, Trinity College, Financial Statement, 2002; UAM, Servicio de Presupuestos 2001; Instituto Superior Técnico, Orçamento do IST, 2004

4. Conclusions

The structure and financing of science and technology is undergoing a slow but profound change. This change can be briefly characterised as a shift from relying on the state to support science to a stronger emphasis on market-based incentives. This paper analyses this shift from a historical perspective, discussing both the analytics and the empirics of the ongoing change. We argue that much of the shift has been driven by the perception of a swing of US policy towards market-based rather than public incentives for science and technology. This, in turn – given the strong economic performance of the US during the 1990s – has influenced policies in most OECD countries, especially in Europe.

In this context, European universities suffering from increasing financial difficulties arising from public budget constraints, expect that closer links between research and application and usefulness in society will translate into more direct and immediate financial flows (Neave and Van Vught 1994; Neave 1995). This perception can lead to an institutional convergence between what universities do (and are supposed to do) and what firms and other agents do. Conceição et al. (1999) consider this convergence a threat to the institutional integrity of the university and the future of scientific research due to the commoditisation of knowledge (Nelson 2004). The issue is not to 'save the university', but rather to understand who will play the fundamental and unique role that universities have played in the overall cumulative system of knowledge generation and diffusion. It appears that the US is not willing to allow their integrity to be jeopardised. By misinterpreting US policies towards university-based research, there is a grave danger that a European university policy towards market-incentives will destroy these basic functions. This would be detrimental to the global production of knowledge and would certainly harm the development prospects of Europe itself, particularly in comparison with the US.

The analysis of the trajectory of US incentives for science and technology shows that during the second half of the twentieth century there has indeed been a steady shift of support from the public to the private sector. Additionally, intellectual property rights and other market-based incentive structures have been extended and used more widely. This trend has been identified and shown to be reason for concern by researchers in the field. We share these concerns, but also find that there has been a core of science and technology in which the state has not pulled back in the US. We find that this is particularly the case for US universities.

The main lesson we take from our analysis is that the US has not compromised public support for core areas or in those fields where there is a clear perception that market incentives are not adequate to meet the strategic targets of US policy. In particular, support for basic research and for university-based research by the public sector in the US has remained strong and steady. Despite the widely-held belief that private revenues linked to R&D results are important sources of university income, we show that this is not the case. A more general implication, beyond the importance of continued public support for universities, is that there is a considerable diversity of policy in US practice, and that all aspects of this diversity should be considered when taking the US as a reference.

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