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University trustees as channels between academe and industry: Toward an understanding of the executive science network

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A B S T R A C T

Policy makers in the United States (US) and the European Union (EU) see "autonomous" research universities as increasingly central to "world class" status, technology development and economic innovation. Trustees or regents (US) and external board members (EU) are seen as a marker of university autonomy. Examining university trustees may shed some light on the role of trustees/external board members play in research strategy, innovation and economic development. Given that a number of trustees of US research universities sit on the boards of directors of large corporations with research interests, we hypothesized that trustees may be an important channel connecting universities to innovation and economic development. To date, university trustees have not been studied as a channel between academe and industry that enables scientific discovery, technology development and economic innovation.

The analysis concentrates on the trustees of the twenty-six private US Association of American Universities (AAU). This organization includes some of the oldest research universities, where trustees have long played an important part. The ties between university trustees and the corporate boards of which they are directors were examined in 1997 and 2005 to see if trustees served as channels between academe and industry. The findings indicate that while the number of trustees stayed the same, there was a drop of roughly one-third of the number of trustees connected to corporations. However the percentage of trustees connected to science-based corporations remained the same. There was an increased convergence between the research fields of a university and the science fields of the corporations to which trustees are connected. Finally, there is evidence that the number of university trustees connected to science-based corporations positively influences the amount of R&D funding a university receives. Given the results, we conclude by theorizing the rise of an executive science network that plays an instrumental role in relations among universities and industry.

1. Introduction

Policy makers see "autonomous" research universities as increasingly central to "world class" status, technology development and economic innovation (Altbach, 2007; European Commission, 2010; Orszag and Holdren, 2009). World class status, technology development and economic innovation are related in that indicators for rankings depend on publications (Dehon et al., 2011), which, in the Science, Technology, Engineering and Math (STEM) fields, are assumed to underpin technology development and economic innovation (National Economic Council, Council of Economic Advisors, and Office of Science and Technology Policy, 2011; European Commission, 2010; World Bank Institute, 2007). Academic patents are generally seen as complementing publications, and as playing a strong part in technology development resulting in economic innovation (Stephan, 2012). Although losing ground, United States (US) research universities still lead the world in academic patents (National Science Board, 2010, 2012). In the 2012 Shanghai rankings, 19 of the top 25 were US research universities, four were in Great Britain (GB), and two were located elsewhere (Academic Rankings of World Universities, 2012). The majority of the universities in the US top ten academic patent rankings were in the Shanghai top 25 (D'Amato et al., 2010). Both the US (whether private or public) and GB have a tradition of autonomous universities, in that they are not directly managed by the state, rather, they have external boards of trustees that hold fiduciary, moral and legal responsibility. In this paper, we explore the part that trustees play in contributing to research, technology development and economic innovation at the highly ranked world-class universities.

There is not a great deal of empirical research on why autonomous universities are the vehicles for cutting edge research with economic development potential. Rankings are based on

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rather limited indicators and do not speak to what management processes contribute to the success of these universities (Saisana et al., 2011). Managerially, the defining characteristic of private US research universities is self-perpetuating boards of trustees that have legal, moral and fiduciary responsibility for these institutions. US public research universities also have trustees with similar authority, although they are usually appointed by state governors. There has been little examination of the part trustees play with respect to shaping how research strategies of these universities intersect with technology development and innovation. This is despite the fact that many of the trustees of leading private US research universities are heads of Fortune 500 and/or research intensive companies and often sit on the Board of Directors of other Fortune 500 and/or research intensive corporations (Pusser et al., 2006).

The study of US university trustees may shed some light on the role of trustees/external board members in research strategy, innovation and economic development. Given that a number of trustees of US research universities sit on the boards of directors of large corporations with research interests, we hypothesized that trustees may be an important channel connecting universities to innovation and economic development. To see if this were the case, we constructed a data set composed of the trustees of 26 private US Association of American Universities (AAU) universities at two points in time, 1997 and 2005, and the corporations that they directed as well as the corporations on which they sat as members of boards of directors. For reasons that will become clear below, we did not include public universities in the analysis. The North American Industry Classification System (NAICS) code was used to categorize each corporation, and a crosswalk was developed between those codes and National Science Foundation (NSF) categorization of the broad fields of science at research universities, allowing us to identify the corporations' academic science fields. Using the same NSF categories, universities top research fields were identified by total R&D dollars expended. We then developed a set of models to explore the relationship between trustees' corporations' science fields, universities' top research fields and R&D funding over time. Given our results, we conclude by theorizing the rise of an executive science network that plays an instrumental role in relations among universities and industry.

Table 1
Association of American Universities US Members 2005.

Brandeis	Purdue	U Iowa
Brown	Rice	U Kansas
Cal Tech	Rutgers	U Maryland
Carnegie Mellon	Stanford	U Michigan
Case Western	SUNY Buffalo	U Minnesota
Columbia	SUNY Stoneybrook	U Missouri
Cornell	Syracuse	U Nebraska
Duke	Texas A&M	U North Carolina
Emory	Tulane	U Oregon
Harvard	U Arizona	U Penn
Indiana	UC Berkeley	U Pittsburgh
Iowa State	UC Davis	U Rochester
Johns Hopkins	UC Irvine	U Southern Cal
MIT	UC Los Angeles	U Texas
Michigan State	UC San Diego	U Virginia
New York U	UC Santa Barbara	U Washington
Northwestern	U Chicago	U Wisconsin
Ohio State U	U Colorado	Vanderbilt
Penn State	U Florida	Washington U
Princeton	U Illinois	Yale

2. Background

There is not a great deal of research on US university boards of trustees. Both public and private US universities have boards of trustees, so there are more than 3000 such boards representing colleges and universities ranging from community colleges and small private colleges to elite research universities. The bulk of the trustee literature is descriptive and proscriptive, aimed at teaching trustees the rules of good stewardship. Although these boards are charged with broad governance of universities and have legal, fiduciary and moral responsibility, most scholars assume that presidents run universities, and that the function of the board is to act as a buffer between the university and the state (Association of Governing Boards, 2007; Chait et al., 1991; Hill et al., 2001; Kerr and Gade, 1989; Madsen, 1997; for exceptions treating public university trustees see Nicholson-Crotty and Meier, 2003; Pusser, 2004).

With regard to research universities, the literature shows that the governors' of the states where they are located generally appoint public research university trustees. Although the trustees are supposed to be above politics, managing universities in the public rather than the private interest, traditionally, trusteeships are given to persons who contribute heavily to the governor's campaign funds and are members of the governor's political party. Therefore public university trustees are often selected for their contributions and loyalty to the governor and his or her political party rather than for their business acumen. In contrast, private research universities trustees are thought to be selected because they are loyal alumni likely to donate to the endowment (Pusser, 2004).

However, trustees of private AAU universities may be different than most other university trustees. The AAU is the oldest and arguably the most elite association of research universities in North America and having membership has shown to be a decidedly positive predictor of an institutions' research capacity (Cantwell and Mathies, 2012). It develops national policy positions on issues related to academic research and graduate and professional education and provides a forum for discussing a broad range of other institutional issues. The AAU was founded in 1900 by the original fourteen universities that offered the Ph.D. Degree, and is a "principals only" organization in that only the presidents are at the table for meetings; substitutes are not acceptable. AAU membership is highly sought after, but granted by invitation only. There were 60 US AAU universities when data were gathered (see Table 1). The AAU institutions consistently score among the highest on all indicators of research: grant and contract funds, citations in research literature, patents, citations in patent literature, revenue generated by licensing, start-up companies, and quality ratings by peers in specialized fields (National Science Board, 2012).

Historically, and presently, the trustees of AAU universities are drawn from the boards of directors of large corporations (Veblen, 1918; Sinclair, 1923; Beck, 1947). Our data revealed that within AAU, there was a marked difference between public and private universities. Private universities trustees were closely interlocked through their corporate directorships. Any one trustee was no more than a half a step away from any other. The trustees met regularly on a face-to-face basis on their corporate and university boards. Public universities trustees were by and large not connected to this network and, when they are connected to corporations, are less tied to patenting firms (see Fig. 1, and Slaughter et al., forthcoming). In 2001, for instance, public universities were tied to 113 (13 percent) of the 866 corporations in the network created by trustee interlocks. Private universities, by contrast, were tied to 789 (91%) of the network.

Despite the dense network of private university trustees, little is known about the trustee selection process. About 70 percent of the private AAU sample were alumni. Given that these universities routinely graduate men and women who disproportionately head the central institutions in the US, ranging from corporations to government, sitting trustees had an ample alumni base from which to select distinguished new trustees (Domhoff and Dye, 1987; Dye,

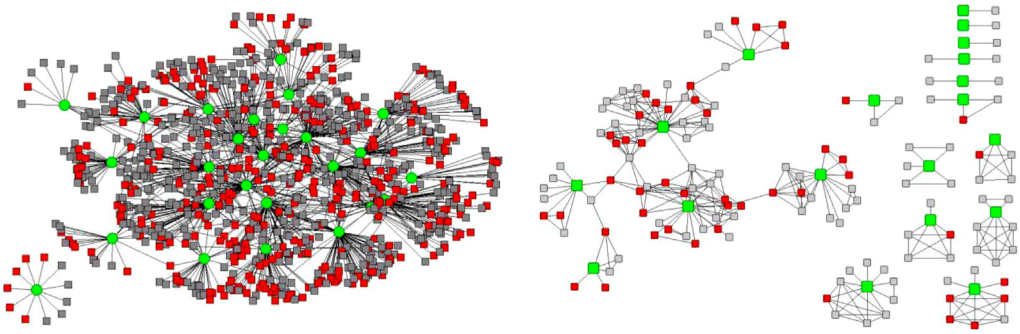

Fig. 1. 1997 AAU organizational networks, by institutional type.

1989, 1994, 2002). However, there is no data that suggests why these particular corporate leaders were selected. Nor do we know why the thirty percent who were not alumni were chosen, although we do know that they had 1.5 times as many corporate ties as alumni, suggesting that board members may be chosen for strategic reasons, including their research interests. Many of the trustees sat on one or more boards of directors of corporations, creating the dense network.

Given that the US has become a knowledge economy seeking to innovate to maintain its place among other global economies, we reasoned that trustees of private universities increasingly may be selected because they represent corporations with interests in research that are similar to those of universities. In other words, university trustees may select new trustees because they represent businesses active in the science fields in which the university is heavily engaged. Trustees may agree to serve at least in part because of these shared interests. University presidents, often represented as voting members on the board of trustees, may also prefer trustees who share the universities' research interest and are likely to support investment in these areas. If this is the case, boards of AAU universities may represent an important channel for innovation, linking universities and corporations.

3. Related literature and theory

Much of the literature that looks at how university research contributes to innovation and economic development focuses on the scientist entrepreneur interface and/or technology transfer structures and faculty (Bercovitz and Feldman, 2011; Colyvas, 2007; Lam, 2007; Shinn and Lamy, 2006; Welsh et al., 2008). Others look somewhat more broadly at channels, paths and chains that link universities and firms, usually focusing on firms (Mueller, 2006). For example, D'Este and Patel (2007) found that the most frequent channels linking academe and industry were consultancy and contract research, and joint research or training. Patenting and spinouts are not used as frequently. There was a wide range of channels (e.g., creation of physical facilities with industry funding, training of company employees through courses or temporary personnel exchange, post graduate training in companies, joint supervision of PhDs, secondments to industry, short or long term, attendance at conferences with industry and university participation, attendance in industry sponsored meetings, creation of electronic networks). The researchers noted that specific fields of study had discrete channels, and that certain industries approached universities in specific ways, depending on their knowledge needs and strategy (see also Bruneel et al., 2010).

Bekkers and Freitas (2008) found 23 channels that linked universities and firms. They noted that firms appeared to define strategies of interaction with universities depending on their present and future knowledge needs, and pursue either collaboration and contract research or intellectual property or various forms of organized activity such as partner programs. Fontana et al. (2006) found that firms that actively screened their environment and voluntarily disclosed internal competencies had a higher propensity to collaborate with academic partners and to cooperate using multiple paths (see also Laursen and Salter, 2004). Stuart et al. (2007) found that many young bio tech firms acted as intermediaries in tripartite alliance chains, entering upstream partnerships with public sector research institutions, and later forming commercialization alliances with established, downstream firms. They examined the alliance activity in a large sample of biotech firms and found that firms with multiple in-licensing agreements were more likely to attract revenue-generating alliances with downstream partners, but that the positive relationship between in-licenses and downstream alliances attenuated as firms matured. The diversity and the quality of the academic connections of firms' principles influenced their chances of successfully acquiring commercialization rights to scientific discoveries in universities.

The studies above identified channels between industry and universities by examining how upper level management of firms connected with academe, rather than focusing on university managements' efforts to connect with firms. None of the studies looked at trustees as a channel, nor did they contrast private with public universities. However, they do suggest that firm managers are aware of knowledge needs, that they screen their environment for opportunities that universities may provide, and that firms' managers' academic connections may be important. As we noted earlier, many trustees of AAU private universities are firm managers and/or sit on boards of directors of firms, and likely are aware of their firms knowledge needs and, by virtue of their trusteeships, of the research in which their universities are engaged.

There is a rich literature in economics (Alchian and Demsetz, 1972; Fama, 1980; Ghoshal and Nohria, 1993) and sociology (DiMaggio and Powell, 1983; Granovetter, 1973; Haunschild and Beckman, 1998; Mizruchi, 1996; Selznick, 1957; Zajac, 1988) that models "interlocks," or networks of corporate boards of directors. Generally, scholars that model interlocks argue that corporate boards of trustees exercise leadership and influence the shape of organizational structure and behavior. Attention is often focused on the director interlock, the case where individuals serve simultaneously as directors on more than one governing board. Studies of interlocks are often based in resource dependence models (Pfeffer and Salancik, 1978) that suggest governing boards are a significant mechanism for pursuing and stabilizing key resources and sources of legitimacy for the organization, and that board interlocks are essential to the board's performance in those roles. Director interlocks have been found to generate substantial effects, including increased organizational control over resources and greater inter-firm cooperation (Burt, 1983); isomorphic adoption of strategic tactics across firms (Useem, 1984); greater access to information and a reduction of information and monitoring costs; enhanced organizational learning (Mizruchi, 1996); greater access to capital (Stearns and Mizruchi, 1993); and the maintenance of relationships with key resource providers. Given that many AAU university trustees are corporate directors densely networked with other corporate directors, some of whom are also university trustees, they are uniquely placed to develop strategic tactics to move information and resources to build channels between academe and industry.

Interlocks are often conceptualized as information portals. One of the most widely invoked new paradigms for corporate performance relies upon the juxtaposition of strategic competition, intellectual capital, and knowledge management (Choo and Bontis, 2002). Given the increasingly high cost of obtaining information and the comparative advantages that accrue to those organizations that capitalize on knowledge, the ability to use networks to trade information, best practices, and innovative strategies is increasingly instrumental to organizational success. Building on earlier work in the sociology of organizations on the structural embeddedness of social capital (Granovetter, 1973), Davis (1991) argues that interlock ties constitute a form of organizational social capital that provides access to essential information, innovation, and strategy, while serving as a key component in the creation of intellectual capital within organizations. Nahapiet and Ghoshal (1998) argue that the structural dimension of social capital "refers to the overall pattern of connections among actors—that is, who you reach and how you reach them. Among the most important facets of this dimension are the presence or absence of network ties among actors" (p. 244). Other research suggests another powerful outcome of board interlocks is an increase of trust between board members and across boards. Huizing and Bouman argue that trust "positively affects the allocative and adaptive efficiency of knowledge markets, which should therefore be cultivated" (2002, p. 201). Consequently, university trustees' familiarity and experience with one another in multiple settings may increase trust and the flow of information both among trustees and between the corporations and universities they govern.

Generally, the literature on corporate board interlocks suggests that board interlocks among research universities may serve many functions, ranging from information portals to creation of trust within networks. However, we are interested in strategic competition and knowledge management (Choo and Bontis, 2002), with appropriate modifications for universities, located in the nonprofit sector but governed by boards of directors drawn from for-profit corporations that often share overlapping research interests. Bercovitz and Feldman (2007) note that the research on search, absorptive capacity, and organizational learning implies that firms emphasizing exploratory research will pursue university interactions. In their study of Canadian firms, they found a strong relationship between firm innovation strategy and firm–university research interactions. Firms that pursued internal exploratory R&D were more likely to have relationships with universities that were exploratory. These firms saw universities as strategic partners "because of their mission, limited market presence and lack of complementary assets, offer [ed] an advantage to firms in appropriating joint research projects results, particularly for projects involving exploratory research" (p. 937). Although Bercovitz and Feldman focus on specific research partnerships between firms and universities, it is likely that firm CEOs and board of director members who sit on university boards of trustees may also see broad strategic advantages to investing in research areas shared by firm and university, irrespective of any specific research endeavor. One of the main policy functions of boards of trustees and members of corporate boards of directors is overseeing strategy, specifically the allocation of resources to key functional activities (Westphal et al., 2001). So too, university board of trustees' members may emphasize university research that aligns with their corporate science fields with future strategic innovations in mind.

With regard to universities, academic capitalism (Slaughter and Leslie, 1997; Slaughter and Rhoades, 2004; Slaughter and Cantwell, 2012) theorizes how segments of universities move toward the market. The theory teases out the ways in which new institutional and organizational structures that link corporations, universities and state agencies, take advantage of the openings provided by the neoliberal state to build knowledge economies. The emerging organizational field (DiMaggio and Powell, 1983) embodied by networked trustees who share research interests may be an intermediating entity that shifts research universities in an entrepreneurial direction. Indeed, we theorize that trustees and senior managers of private AAU universities may constitute an executive science network that is increasingly important to the management of university–industry science. As directors of both universities and science based corporations, these board members are in a unique position to influence the resourcing of discovery and innovation from the highest level or formal organizational authority. Trustees and senior managers may play a part in shaping national research policy to promote technology innovation and economic development, make investment decisions at universities that prioritize common areas of interest, explore new areas for future investment, and put industry funds into research areas likely to provide relatively short-term payoff. The network may create trust that allows directors of science-based firms to pursue broad strategic goals that call for knowledge sharing and work on common problems such as shifting national policy toward technology innovation and economic development. At the same time, trustees and senior managers at specific universities may pursue competitive advantages by treating the university as a firm that can maximize profits for both academe and industry.

However, university trustees who sit on corporate board(s) of directors have various obligations and constraints that may create challenges to developing research strategies that bring firms' fields of corporate science and universities' research fields together. Chief among these are conflicts of interest. The closer the research interests of firms represented by trustees come to universities research portfolios, the greater the possibility of institutional conflict of interest (ICOI) [Slaughter et al., 2009]. Conflict of interest (COI) has been studied primarily at the level of individual researchers (Bekelman et al., 2003; Boyd et al., 2004; Cho et al., 2000; Van McCrary et al., 2000), but ICOI is a growing concern for research universities (Association of American Medical Colleges and AAU, 2008). Yet to date there is very little empirical work on ICOI and what there is has not included trustees (Bartlett, 2008; Campbell et al., 2006, 2007; Reeser et al., 2008; Weissman et al., 2008; Wolf et al., 2008). We address the knotty issue of institutional conflict of interest in the conclusion.

In sum, an executive science network presents a paradox. When trustees simultaneously sit on boards of directors of businesses with corporate science fields that match those of their university, they may generate synergy that stimulates research, discovery, and technology development in those fields that may lead to economic innovation. At the same time, the network may increase similarity between the research interests of trustees and universities, creating new challenges with regard to ICOI.

4. Research questions

We reasoned that trustees who sat as boards of directors of science corporations likely wanted their corporations' fields of science to prosper. Indeed, some trustees may have chosen to serve on university boards because the science fields of their corporations matched the research fields of the university. As corporations have diminished their commitment to research laboratories, e.g., Bell Labs, that explore basic technology research in favor of research concentrated on product development, they have to some degree turned to universities for innovative, entrepreneurial research (Salter and Martin, 2001; Sampat and Lichtenberg, 2011; Toole, 2011; Varma and Worthington, 1995). The years 1997–2005 likely capture this transition. By the mid 1990s, the contribution universities could make to American competitiveness and economic innovation was well understood, and, given the staggered appointment of trustees to university boards, it may have taken until 2005 for science corporation trustees to appear and have an impact on board policy. Shared interests in science and research may contribute to close connections between trustees' corporations and university research, e.g., licensing of university intellectual property, corporate support of university research through R&D funding, exchanges of personnel. In their governing capacity, trustees could also steer universities to strengthen university research fields matching with corporate science fields though investment in star faculty and/or research facilities, ranging from medical schools and hospitals to laboratories, centers and institutes. In other words, we thought that over time science corporations represented by trustees might become an important channel between the world of industry and academe, with implications for technology development and economic innovation.

Conversely, university presidents, often voting members of the board of trustees and also often members of corporate boards of directors (Goldschmidt and Finkelstein, 2001; Slaughter, 1990), may work with sitting trustees to select new trustees whose corporate science fields match university research fields in order to further strength top university research fields. AAU university presidents and senior management have long committed to maximizing prestige (Bowen, 1980). As the rankings game became more important and research universities began to aggressively seek "world class" status, R&D funds became an ever more important indicator of rank and prestige (Marginson, 2007; Teichler, 2011). At the same time, the cost of research, as measured by article production, increased, making external revenues captured by R&D success more important (National Science Board, 2010). The years 1997–2005 likely bracket this shift to university concern with rankings in the global arena. If senior university managers put a premium on the pursuit of additional research funding, they would be likely to work with their boards to select trustees who might help them capture additional funding, i.e., have knowledge of and ties to areas similar to a university's research interest(s) and that, as a result of those ties, universities might be more successful in securing research funding in those areas. Thus, we developed the following hypotheses:

1. Over time, more trustees will be connected to science corporations.
2. Over time, university research fields, as represented by various types of research funding, align with universities corporate science fields, as represented by the scientific fields in which trustees' corporations are active.
3. Over time, universities' corporate science fields positively influence the amount of research and development (R&D) funding universities receive.

5. Methods

5.1. Sample

The sample included only voting members of boards of trustees of the 26 private US AAU universities and the publicly traded business corporations to which the trustees' were linked by concurrently sitting on the corporate board of directors. Public AAU universities were not included because, as noted above, they are not part of the dense network of trustees that simultaneously sit as boards of directors of corporations. Although a number of the private university trustees were also CEOs of corporations, these corporations were not part of the sample because we wanted parallel authority structures—corporate boards of directors and university trustees. Because the trustees "day jobs" as CEOs were not part of the sample, trustees' corporate representation is underestimated. The voting trustees linked universities and corporations at the highest level of governance of each type of organization.

Trustee and corporate data were collected at two points in time, 1997 and 2005. The data on university trustees and the corporations that they represented were drawn from the Research University Trustee database (for details see Slaughter et al., forthcoming). The data include university, trustee name, the name of the publicly traded corporations on which the trustee sits as a member of the board or boards of directors, and the NAICS code. NAICS is the standard classification system for businesses developed by national statistical agencies (United States Census Bureau, 2010). When a university trustee sat on multiple corporate boards each trustee-corporate connection was considered as a single case.

5.2. Matching trustees corporations with universities' academic fields of science

Trustees sat on boards of directors of non-science and science corporations. Given our concern with trustees as channels between industry and university research, we were primarily concerned with the science corporations trustees represented. We wanted to be able to characterize these science corporations in terms of their fields of science. We reasoned that many successful corporations operate in a knowledge economy and manufacture products that embody science and have areas of scientific expertise. Therefore, we wanted to identify trustees' corporations' scientific areas of expertise, or corporate science fields, so they could be related to university research and then to universities success in obtaining research funding.

We assigned each corporation represented by a trustee to an NSF broad field of science, creating its corporate science field. Development of a crosswalk was required because there is no publicly available direct database crosswalk between corporations' NAICS codes and fields of science.[1] This required multiple steps. In the first step, we matched corporate NAICS codes to a corresponding Classification of Instructional Programs (CIP) code. The US Department of Education's National Center for Educational Statistic's (NCES) provides a national (US) taxonomy that allows the tracking, assessment, and reporting of fields of study and program completion activity at colleges and universities through CIP codes (National Center for Educational Statistics, 2010). The 6 digit CIP codes are broken into 3 sections (2-digits per section). We used the first 2-digit section, which identifies academic programs by large discipline areas (ex: 14 = engineering, 40 = physical sciences, etc.), of the third revision (2000; National Center for Educational Statistics, 2010). We matched all 2007 NAICS (N = 2328) classifications to a CIP code on the basis of a corporation's area of activity and scientific specialization.

[1] A crosswalk between CIP, SOC (Standard Occupational Class), and NAICS is maintained by the National Crosswalk Service Center (NCSC – www.xwalkcenter.org). NCSC is a federally (U.S.) funded clearinghouse of classification information on occupations, training programs, and industry. The NCSC crosswalk however had multiple cases of CIP codes for each NAICS classifications (most likely due to the inclusion of the SOC in the crosswalk). For this paper, we needed a single 1-1 crosswalk and thus required building our own using the NCSC crosswalk as a guide.

The idea was to make a 1-1 crosswalk between corporate fields (NAICS) and academic fields (CIP). For example, Pfizer is a large, multi-national corporation that has an assigned NAICS code of 325412, pharmaceutical preparation and manufacturing. Pfizer was assigned a CIP code of 26, biological and biomedical sciences because its area of research activity and scientific specialization is in pharmaceuticals. Another example is Baker Hughes Inc. that has an assigned NAICS code of 333132, Oil and Gas Field Machinery and Equipment Manufacturing and was assigned to the CIP code 40, Physical Sciences.[2] Appendix A contains an example of an entire institution's trustees corporations NAICS codes matched to CIP fields. This method may have created some questionable instances of corporate CIP classification. However, no other method was available to match a corporation's classification (NAICS) to a single academic field (CIP), so we went forward, and hope that this article will prompt discussion and improvement of these classification schemes.

Next we collapsed the CIP codes into broad academic fields (science and non-science) using the crosswalk between NSF's fields of science and engineering and (NCES) CIP codes from the latest available survey of Research and Development Expenditures at Universities and Colleges (2009 academic R&D expenditures survey; National Science Foundation, 2010). Separating science from non-science corporations (e.g., finance, insurance, real estate) allowed us to focus on the science corporations.

For trustees' science corporations, we used 10 broad fields of science (NSF-CIP crosswalk contains 9 fields, but we separated Agricultural out from Life Sciences field, creating a tenth field). We separated Agricultural from Life Sciences mainly because we wanted differentiate agricultural from biomedical research, which receives more funding than other broad fields. Additionally, a number of land grant universities (e.g., University of Arizona, Cornell University, Texas A&M), with agricultural schools are funded by the US Department of Agriculture (USDA) through processes that are often less competitive than other federal research funding and these funds may be less closely tied to trustees' corporations than others. The broad fields of science in order of total research funding for 2005 (last year of data in sample) are: Life Sciences, Engineering, Physical Sciences, Agricultural Sciences, Environmental Sciences, Social Sciences, Computer Sciences, Psychology, Other, and Mathematical Sciences. Profiles were then developed for each university of the corporate science fields represented by trustees.

Preliminary analysis revealed that the top three corporate science fields represented the vast majority of universities trustees' corporate science connections (90–95%). To streamline our models, we only used each university's top three corporate science fields. For example, if University X had 8 trustees who represented 12 science corporations in 4 broad science fields, we only used the top 3 fields in the analysis: 4 of the corporations in 1 field, 4 in another, and 3 in yet another; the remaining corporation was in a field that differed from all others and thus was not included.

5.3. Analytic strategy

First, we wanted to see if universities' trustees were more likely to represent science corporations over time. For the years 1997 and 2005, basic descriptive statistics and a number of paired sample *T* tests were completed to see if the variables in this analysis were significant, e.g., number of trustees per university, number of trustee connections to all corporations per university; number of science corporations per university. We then compared all trustees' corporate connections and trustees' science corporation connections for 1997 and 2005.

Second, we wanted to know if universities' corporate science fields and research fields were congruent or became congruent over time. Unless the there were some similarities between the corporate science fields and university research fields, there was little probability that corporate science fields would influence success in winning grants and contracts. We identified universities' corporate science fields by the cross walk described above, and were then able to see how they mapped onto university research expenditures. Two profiles for each university were developed based on the corporate science fields and research fields represented. A university's research expenditures were the marker (unit) of alignment, on the grounds that funding was a proxy for research activity, and increased activity in broad fields of research that mapped onto the corporate science fields indicated congruence.

Third, we developed a series of control variables so that we could understand the degree to which universities' corporate science fields independently influenced university success with regard to grants and contracts. First, we controlled for the growth of research funding from 1997 to 2005. Then we drew on the literature that identifies the most powerful predictive university characteristics with regard to research success to identify the following control variables: faculty salaries, number of faculty members, presence of a medical school, and presence of a hospital (Feller, 1996; Geiger, 1996, 2004; Mathies, 2010; Savage, 1999; Teich and Gramp, 1996). Data for the control variables were collected from the Integrated Postsecondary Education Data System (IPEDS) maintained by the National Center for Educational Statistics (NCES, 2009) from the U.S Department of Education.

Lastly, we utilized a set of dependent variables—total R&D, federal R&D and industry R&D, that captured research funds for which universities can compete. Federal and industrial R&D speak for themselves; total R&D includes funds that institutions contribute to their faculty's research, foundation, state, federal, industrial and other funds—in other words, all sources of funding that universities receive. Data on research expenditures was obtained from the Research and Development Expenditures at College and University survey operated and maintained by NSF (National Science Foundation, 2007). The three dependent variables and the control variables were used to develop six ordinary least squares (OLS) regression models analyzing the degree to which universities' corporate science fields predict grant and contract success with regard to various research revenue streams at two points in time, 1997 and 2005. Yearly research expenditures in a given year were used as the measure of research conducted by a university.

OLS models are well suited for exploring linear relationships as they yield easy interpretation of marginal effects. This approach fit well with our data because the relatively small number of observations makes time series modeling difficult.[3] However, the OLS models, like other cross-sectional data, are limited in that they do not explore time interactions. Thus, discussions of change over time are guided by interpretations of sequential cross-sectional (one

[2] A second method was used to match CIP codes to NAICS codes on the basis of a corporation's area of operations. For the two examples listed, both Pfizer and Baker Hughes were assigned CIP code 14, Engineering, due to both corporations manufactured a product. To streamline the analysis the choice was to go with the first method only.

[3] The main questions revolve around two issues, the number of observations and time between observations. Modeling time series with a few number of observations, as this study has, is fraught with difficulty. A general rule of thumb is to have at least 50 observations and in our models we had 49 (25 in 1997 and 24 in 2005 due to effects of Hurricane Katrina [Tulane] and a statistical outlier [Johns Hopkins]). As for timing, ideally for time series or panel data models data are measured at regular intervals. Our data have two time periods eight years apart. However, planned future data collection in 2012 of same data in this study would provide data for analysis in regular intervals over a 15-year period (start [1997], middle [2005], and end [2012]).

point in time) findings, rather than through a statistical analysis of change over time. It is important to note these OLS model do not permit strong causal inferences. Hence this study examines the associations between research funding and science corporation representation on university boards.

6. Findings

6.1. Description of university trustees connections to all corporations, 1997 and 2005

The average size of a university board was just under 46 voting members in both years of the sample (45.9 1997, 45.7 2005, see Table 2). The difference in the number of trustees at the two points in time was not significant (t = 0.179, p > .860) indicating that the number of university trustees was similar for 1997 and 2005. University trustees sat on the boards of non-science (e.g. banks, media companies) as well as science corporations (e.g. pharmaceutical manufactures, natural gas distributors, software publishers). The mean number of university–corporate connections (i.e. university trustees sitting on corporate boards) dropped significantly over the years (50.8 in 1997 to 32.6 in 2005; t = 5.375, p < .001). The mean number of trustees with any type (science or non-science) of corporate connections for a university board dropped significantly from 20.5 in 1997 to 17.3 in 2005 (t = 3.047, p < .005). A number of trustees (39.8% 1997, 52.1% 2005) sat on only one board, while the remaining (60.2% 1997, 47.9% 2005) were on more than one board. For example, a university might have 21 trustees sitting on the boards of 50 corporations. These 21 trustees would account for 50 university–corporate connections.

The proportion of university trustees sitting on a corporate board also significantly declined between years 1997 and 2005 (46.6% in 1997, 37.7% in 2005; t = 3.351, p < .003). At 22 (85%) of the 26 universities the number of all corporations to which trustees were connected declined. The mean decline was 36%; the largest decline 61%. At the four universities that had increased trustee connections to corporations, the greatest increase was by 4 connections or an 11% increase. In short, while the number of trustees did not significantly change, there was a significant decrease in the number of trustees connected to corporations between 1997 and 2005. The majority of the university's boards were less connected to corporations and these decreases were, for the most part, quite substantial. The few universities that did increase their corporate connections had relatively small increases.

6.2. Description of trustees' connection to science corporations from 1997 to 2005

As noted above, university trustees' could sit on the board of directors of non-science or science corporations. Because we wanted to understand how trustees' corporations' might affect university research funding, we were primarily concerned with trustees' science corporations. To characterize trustees' science corporations, we ranked each corporation's fields of science based on the percentage of corporations in the various fields of science

Table 2
Number of trustees, all corporate connections, and trustees connected to all corporations.

	1997	2005
Total number of trustees	1194	1189
Mean number of trustees	45.9	45.7
Total number of university–corporate connections	1321	848
Mean number of university–corporate connections	50.8	32.6
Total number of trustees connected to corporations	533	449
Mean number of trustees connected to corporations	20.5	17.3

(see list in Section 5.2). Between 1997 and 2005, there was a 1% non-significant decrease of the proportion of trustees' corporations' science fields (t = .527, p > .603). Streamlining the analysis and examining only the top three science fields, the results were similar. There was a 1% non-significant decrease of the proportion of trustees' corporations in the various science fields (t = .451, p > .656). Thus, our first hypothesis—that the number of trustees connected to science corporations will increase—was not confirmed. Rather, the number of connections to science corporations remained approximately the same. This held true as well when only examining trustees' science corporations top three sciences fields. However, that the percentage of corporate connections to science fields remained the same when the overall number of trustees connections to non-science corporations dropped significantly between 1997 and 2005 indicates that trustees who sat on the boards of science corporations had a stable interest in research universities.

6.3. Alignment of the fields of science: university–corporate connections and research expenditures

Two profiles of each university's corporate science fields based on two years of data (1997 and 2005) were developed. The three top corporate science fields from each university's profile were compared to its R&D expenditures for 1997 and 2005 to determine whether a university's corporate science fields and its research fields were alike. We compared the fields in a number of ways. First, the university's top corporate science field and the universities' top field of research as represented by the proportion of the total R&D were compared for each university to see if they were similar. In other words, the single top corporate science field based on a university's trustees' corporate connections was compared to the university's top field of research based on R&D funding. There was some alignment (6 of 26 universities, 23% in 1997; 5 of 26 universities, 19% in 2005) between the top corporate science fields and the top research field, but overall the alignment between the two was weak. Our second analysis was expanded to see if the university's top field of research matches one of its top three corporate science fields. There was much stronger alignment. More than three-fourths (20 of 26, 77% in 1997; 21 of 26, 81% in 2005) of the universities' top field of research matched one its top three corporate science fields. In other words, a match between a university's top research field and one of its top three corporate science fields was likely. We also compared the top corporate science field to the top three research fields and found similar alignment (17 of 26, 65% in 1997; 19 of 26, 73% in 2005). Finally we compared the top three corporate science fields to the top three research fields[4] and we found an increasing alignment between the two. In 1997, 16 universities (62%) had 2 or more matches while in 2005 there were 21 universities (81%) with 2 or more matches between the groups, thus confirming our second hypothesis, that over time, university research fields align with universities' corporate science fields.

6.4. R&D expenditures

The majority of all R&D expenditures came from a university's top field of research. Between 1997 and 2005, the top field increased significantly as a proportion of all R&D expenditures (59% in 1997, 64% in 2005; t = −5.031, p < .001). In terms of raw dollars, the R&D

[4] This was not necessarily a direct #1 corporate science field = #1 field of research and the #2 corporate science field = #2 field of research. Rather it was the #1 corporate science field being represented within the top three fields of research, and the #2 corporate science field being represented within the top three fields of research, etc.

Table 3
Means of dependent and independent variables.

	1997	2005
Total R&D expenditures	193.1	369.8
Federal R&D expenditures	140.1	276.2
Industry R&D expenditures	13.0	19.9
Proportion of #1 corporate science field	27.5%	25.5%
Proportion of #2 corporate science field	15.5%	15.8%
Proportion of #3 corporate science field	10.6%	10.8%
Total number of faculty	850.1	983.4
Average faculty salary	73.0	99.5
Hospital	36%	33%
Medical school	72%	71%

Note: R&D expenditures in nominal millions $.
Note: faculty salary in nominal thousands $.

expenditures from the universities in sample grew 85% from $5.6 billion in 1997 to $10.5 billion in 2005. This growth is on par with the overall growth of R&D expenditures of all universities in the U.S during this time frame (88% increase, $24.3 billion in 1997 to $45.7 billion in 2005; NSF 2007[5]). In short, between 1997 and 2005 substantially more R&D funding was flowing into universities, more of this funding was going into universities' top field of research and this field was very likely to align with one of their top three corporate science fields.

6.5. University trustees' corporations and university R&D expenditures

A series of six OLS regression models were developed to test whether a university's top corporate science fields can predict its R&D funding. The six models were broken into three groups based on the dependent variables (total R&D, federal R&D, and industry R&D) and two points in time (1997 and 2005).[6] Table 3 presents the means of the dependent and independent variables used in the OLS models. The proportion of the top three corporate science fields represented within all academic fields, via the corporate–university trustee connections, were calculated and used as independent variables. The total number of faculty, average faculty salary, whether the university had a medical school or a hospital were used as control (independent) variables. The latter two are perhaps particularly important for life science (NIH) funding, the largest of all federal R&D grant programs. As Table 3 shows, the mean R&D expenditures for all three categories (total, federal, and industry) increased between 1997 and 2005 with total and federal R&D expenditures showing the most growth. The mean number of total faculty and the average faculty salary also increased during this time period. The mean proportions of science corporations represented by trustees remained roughly the same between 1997 and 2005. Just over one-fourth of all corporations' connections, science and non-science, represented by trustees were in a universities' top corporate science field. When the second and third fields of corporate science are considered, the second field accounted for roughly 15% and the third for 11%.

6.5.1. 1997 models

In examining the 1997 models, the OLS models for total R&D and federal R&D expenditures were significant while the industry R&D model was not. None of the corporate–university connections variables were significant regardless of model (dependent

[5] Dollar values are shown in nominal values.
[6] For the 1997 and 2005 models, Johns Hopkins University was removed from the analysis due their Total and Federal R&D expenditures were substantially larger (outlier) than the rest of the universities in the sample. For the 2005 model, Tulane University was also removed from the analysis due the effects of hurricane Katrina had on its operations.

Table 4
1997 OLS regression models.

	Total	Federal	Industry
Model significance	0.046	0.034	0.611
R	0.724	0.734	
R^2	0.525	0.545	
Constant	−376.27**	−380.42**	
	(173.4)	(132.5)	
Proportion of #1 corporate science field	107.60	165.81	
	(199.7)	(152.5)	
Proportion of #2 corporate science field	771.40	510.54	
	(481.6)	(367.8)	
Proportion of #3 corporate science field	−753.07	−338.78	
	(583.6)	(445.7)	
Total # of faculty	0.06	0.06*	
	(0.04)	(0.03)	
Average faculty salary	5.28***	4.66***	
	(1.8)	(1.3)	
Hospital	−16.36	−5.27	
	(41.5)	(31.7)	
Medical school	94.82*	62.6	
	(51.3)	(39.2)	

Note: standard errors in parentheses.
* $p < .10$.
** $p < .05$.
*** $p < .01$.

variable) [see Table 4]. For the total R&D expenditures model, only the average faculty salary and the presence of a medical school were significant factors. Every $1000 increase in faculty salary brought on average, $5.28 million in total R&D funding. If a university had a medical school, it brought on average $94.82 million of total R&D funding. For the federal R&D expenditures model, the total number of faculty and average faculty salary was significant. For every additional faculty member added, universities received on average $60,000 of federal R&D funding. For every $1000 increase in faculty salary there was on average an increase of $4.66 million in federal R&D funding.

6.5.2. 2005 models

In examining the 2005 models, as in 1997, the OLS models for total R&D and federal R&D expenditures were significant. In contrast to 1997, the 2005 model for industry R&D was significant (see Table 5). For the total R&D expenditures model, the total number

Table 5
2005 OLS models.

	Total	Federal	Industry
Model significance	0.012	0.012	0.087
R	0.792	0.794	0.703
R^2	0.627	0.630	0.494
Constant	−701.29**	−601.91**	−35.87
	(305.6)	(227.4)	(53.5)
Proportion of #1 corporate science field	591.27*	332.88	172.20***
	(322.8)	(240.2)	(56.5)
Proportion of #2 corporate science field	657.45	865.26*	−83.10
	(620.7)	(461.9)	(108.7)
Proportion of #3 corporate science field	188.65	−114.37	−48.81
	(947.7)	(705.2)	(165.9)
Total number of faculty	0.18**	0.13**	0.01
	(0.08)	(0.06)	(0.01)
Average faculty salary	5.34**	4.90**	0.16
	(2.35)	(1.7)	(0.4)
Hospital	52.87	27.93	20.02
	(73.7)	(54.8)	(12.9)
Medical school	103.77	62.7	−9.19
	(79.9)	(59.5)	(13.9)

Note: standard errors in parentheses.
* $p < .10$.
** $p < .05$.
*** $p < .01$.

of faculty, the average faculty salary and the top corporate science field were significant variables. For each faculty member added there was on average $180,000 in total R&D funding. For every $1000 increase in faculty salary, there was on average a $5.34 million increase in total R&D funding. For every 1% increase in the proportion of trustees' connected to corporations' in a universities' top corporate science field, there was on average a $5.91 million increase in total R&D funding. To put another way, the more a university increased the numbers of trustees who represented corporations in their top corporate science field, the greater its total R&D funding.

For the federal R&D expenditures model, average faculty salary, the total number of faculty and the second corporate science field were significant variables. Every $1000 increase in faculty salary brought on average $3.5 million in federal R&D funding. For every additional faculty member added, federal R&D funding on average increased $130,000. For every 1% increase in trustees' representing science corporations in their university's second ranked corporate science field, universities' federal R&D on average increased $8.65 million. In essence, this suggests that the more a university increased its connections to trustees tied to corporations that operate in its second ranked corporate science field, the greater the R&D funding from federal sources.

For the industry R&D model, the only significant variable was the proportion of trustees (of the all corporate connections, science and non-science) connected to corporations' in a universities' top corporate science field. Every 1% increase in the proportion brought an average $1.72 million in industry R&D funding. In short, the more a university increased its trustees operating in its top corporate science field the more it was rewarded with industry R&D funding.

Generally, our third hypothesis—over time, universities' corporate science fields positively influence the amount of research and development (R&D) funding universities receive was confirmed. Although the degree to which the corporate science fields predicted research expenditures varied by model—total R&D, federal R&D, industry R&D—in 2005 all were positive.

6.5.3. 1997 and 2005 models

Within the two sets of models (1997 and 2005), the significance of the corporate science fields, faculty salary, and presence of medical schools stand out. First, the variables for either universities' first or the second corporate science fields were significant in 2005 but were not in 1997 models, suggesting that our third hypothesis—over time, universities' corporate science fields positively influence the amount of R&D funding universities receive—has merit. The lack of significance in the 1997 models and the significance in the 2005 model suggests university corporate ties have become more important over time for universities' success in winning R&D funding. Second, the average faculty salary was significant in numerous models across R&D funding sources and years. Using faculty salary as a proxy for prestige (higher the salary, the higher prestige of university[7]) suggests that universities that were more prestigious received more R&D funding than their less prestigious counterparts. Third, the presence of a medical school was significant in the 1997 total R&D expenditures model; however, this was not the case in the 2005 total R&D model. This is particularly interesting given that the proportion of all R&D funding for the universities in the sample coming from the life sciences grew from 53.7% in 1997 to 62.1% in 2005.

[7] This was intended to be a simple, straightforward measure (proxy). As such, it does not account for differences in costs-of-living between the locations of the universities in the sample, which could contribute to differences in faculty salary.

7. Discussion

To date, university trustees have not been studied as a channel between academe and industry that enables scientific discovery, technology development and economic innovation. Because trustees of the 26 private AAU universities are also frequently members of boards of directors of corporations with research interests, we thought they might provide such a channel. Given the growth of science intensive knowledge economies, policy makers in many nations look to university research to stimulate technological development that will lead to economic innovation that, in turn, will promote economic prosperity (European Commission, 2010; National Economic Council, Council of Economic Advisors and Office of Science and Technology Policy, 2011; Slaughter and Cantwell, 2012; Suresh, 2011; United Nations Millennium Project, 2005; World Bank Institute, 2007). Policy makers are increasingly concerned with locating, creating or sustaining channels between industry and academe. Our findings suggest that trustees of private AAU universities may provide an important channel.

At first glance, the drop in the number of trustees with corporate connections raises some questions about their importance as a channel. Although the number of trustees remained approximately the same between 1997 and 2005, the number of all corporate connections dropped by about one-third, and the number of trustees with any corporate connection dropped by about 10 percent. There are a number of possible explanations for this. The most likely is the increase in privately held corporations, including public corporations that were taken private, in the period under study (The Economist, 2012). We tracked only trustee connections with publicly traded corporations, not with privates, largely because of ease of access to data. The rapid growth of non-profits during this period also may have increased competition for trustees (Wing et al., 2009). Presumably many non-profits, whether universities or other types of organizations, seek to secure trustees with corporate connections because they are potential financial advisors and/or donors. Universities may not offer trustees the same type of compensation or fees as other non-profits, making trustees more difficult to recruit (Ahn et al., 2003). Another possibility for the decline of trustees with corporate connections is that the economic climate of the study period (1997–2005) was marked by the dot.com bubble (1997–2001), followed by an eighteen month downturn that wiped out $5 trillion of value in technology firms and the difficult financial climate may have made corporate leaders less willing to serve (Beattie, 2011; Weinstein, 2010).

However, the percentage of trustees representing science corporations did not drop, suggesting trustees who are directors of these corporations continued to be committed to a presence at research universities. The persistence of these trustees suggests that they may see sitting on the boards of research universities as important to their businesses. In other words, trustees of science corporations see their service as providing a useful conduit between universities and industry.

The analysis shows that corporate science and university research were more alike in 2005 than 1997, suggesting convergence. However, this may be an artifact of the concentration of more and more R&D funding in universities' primary research fields, which are very like corporate science fields. This concentration suggests that US federal research policy intermediates between university research and corporate science by establishing or preferring programs in the various mission agencies that are designed to promote economic growth as well as accomplish agency goals. The shift in federal policy to use research funding to stimulate economic development is well documented (Slaughter and Leslie, 1997; Slaughter and Rhoades, 1996, 2004, 2005). In response to legislative changes and federal policy initiatives, federal agencies began to structure a greater share of their subsidies, e.g., research grants, to stimulate entrepreneurial research and economic innovation the starting in the late 1980s (Slaughter and Rhoades, 1996, 2005). By 2011, the director of the NSF was unveiling the Innovation Corp (I-Corp):

> [I-Corp] will create a new national network of scientists, engineers, innovators, business leaders, and entrepreneurs. It will help strengthen our national innovation ecosystem. Innovation Corps awards will help to strategically identify nascent science and engineering discoveries, and will leverage NSF's investment in basic research for technology innovation. Universities and academic institutions will be key partners in the I-Corps national network (Suresh, 2011).

Even though NSF is the agency of basic science it is nonetheless in the economic innovation business, and presumably has a strong interest in ensuring that the revenues for which universities compete are expended on the type of research it seeks to promote. Similarly, NIH, the largest federal funder of university R&D, has played an important role in economic innovation. Between 1982 and 2006, one-third of all drugs and nearly 60 percent of promising new molecular entities approved by FDA cited either an NIH funded publication or a patent based on NIH funded research (National Institute for Health, 2011). The NIH promoted "translational research," aimed at converting basic scientific discoveries financed by the NIH into drugs and medical devices (Baskin, 2011). In sum, science policy that makes available research funds for universities' convergent corporate science and research fields may underwrite the infrastructure that allows trustees to deepen channels between industry and academe.

It is possible that university trustees and senior university managers have played a role in shaping federal science policy to prefer science that thrives on university–industry relationships. For example, throughout the 1980s and 1990s, agenda setting policy groups such as the Business-Higher Education Forum, the Carnegie Commission on Science, Technology and Government, the Council on Competitiveness brought together corporate and university leaders to push for legislation that promoted use of science and technology to enable US economic innovation to keep the US in a dominant global position (Slaughter and Rhoades, 2005). While we have not analyzed these bodies in detail to ascertain how many were trustees in our sample participated in them, we do know that a number of trustees representing science corporations were on these bodies, as were a number of presidents of AAU universities. This suggests a complex policy making process involving trustees, university presidents, politicians and federal agencies that may lead to subsidies in areas where universities research and corporate science fields are similar.

Both university trustees and senior management may see it as advantageous to invest in universities' corporate science fields, trustees because they have an interest in science relevant to their corporations, senior management because they see that concentrated research investments may be necessary to win federal dollars, both trustees and senior management because they wish to increase university research funding, reputation and prestige. Investment may take many forms, for example infrastructure, new centers and institutes, various offices—technology transfer, research parks—and enterprises—spinoffs—as well as recruitment of star faculty (Zucker and Darby, 1996, 2007). Although we cannot directly address whether research investment decisions made by trustee and senior management results in success in winning R&D, our analysis indirectly confirms it in that in 2005, universities' corporate science fields predicted increases in all types of R&D (total, federal industrial) and the amount of the increase outweighed other predictors.

7.1. Total R&D

Total R&D is comprised of funds from the federal government (federal R&D), foundations, e.g. the Gates Foundation, state governments, e.g. California, Massachusetts, industry, e.g., grants from Pfizer, and from the universities' own funds, e.g., institutional funds. The breakdown of these funds in 2005 for all American universities was: \$29.2 billion from federal sources (64%), \$8.26 billion from institutional funds (18%), \$2.94 billion from state and local government sources (6%), \$2.29 billion from industry sources (5%), and \$3.09 billion from other sources (7%). The greatest increase in funds since the 1980s was in institutional funds, which were \$835 million in 1980 and \$8.26 billion in 2005, followed by industrial funds. In other words, American universities were spending more internal funds to leverage various external research revenue streams.

In 2005, for total R&D, every 1% increase in the proportion of trustees' corporations' located in a university's top corporate science field, brought on average a \$5.91 million increase. A university's top corporate science field is likely the field of greatest cumulative investment on part of corporations, representing areas of established business and reliable profit. Trustees representing corporations in the universities' top fields may seek to leverage total R&D dollars in areas relevant to what is likely their top science priority. They are probably interested in maintaining university research in these fields to capture important new technology developments, e.g., improvements, upstream technology, new members of patent families. Senior university management likely play an important part with regard to total R&D as well, since that this category incorporates all research dollars, including the 18% that comes from institutional funds. Given the convergence of university research and corporate science fields, senior university management may try to recruit trustees in their top corporate science fields because they are important for steering investments to their top research fields, and strength in these fields may increase success in winning federal grants and contracts, building university prestige and reputation, in which trustees are also interested.

7.2. Federal R&D

In 2005, with regard to federal R&D, for every 1% increase in a university's number of trustees who represent a corporation in the universities second ranked corporate science field, there was an \$8.65 million increase in federal R&D funding. The second ranked corporate field accounted for the greatest dollar increase across all types of funding—total, federal, industrial. Trustees representing science corporations may see universities as laboratories to explore new developments in entrepreneurial science. The second ranked science field may be where these trustees expect universities to discover new technologies for future products and new business areas. If trustees are channels between industry and academe, then they may look to universities to explore research that will be valuable to corporations six to ten years out (Salter and Martin, 2001; Sampat and Lichtenberg, 2011). The second ranked field may be the site where these trustees stake out broad areas of future technology investment. Alternatively, the second ranked science field may account for the greatest dollar increase across all types of research because more federal dollars are available in these areas due to federal research policy that prioritizes investment in entrepreneurial research designed to stimulate technology development and economic innovation. As noted above, processes that lead to federal R&D funding in entrepreneurial areas are complex, iterative, and ongoing. Corporations and universities may have contributed to setting policy agendas that concentrated funds in the second ranked corporate science fields that they seek to develop for the future.

7.3. Industry R&D

In 2005, a university's top corporate science field also predicted an increase in industrial R&D of $1.72 million per 1% increase in the percentage of trustees representing a corporation in the university's top corporate science field. While the dollar increase is not as great as federal R&D or total R&D, this finding had the highest level of significance. Moreover, the percentage of academic R&D funds universities received from industry, while still relatively small, grew faster than total federal R&D or federal R&D during the period of the study. It may be that trustees' science corporations put industry funds into their universities academic research when top ranked fields of corporate science may yield the possibility of intellectual property claims or short-term technology development.

7.4. Synopsis

In sum, university trustees that represent science corporations may create channels with industry that allow them to draw on academic research that enables them to maintain and expand their knowledge in their top science field (total R&D), explore new areas of expertise for future investment in their second ranked corporate fields (federal R&D) and invest research in areas likely to provide immediate payoff, claiming and protecting knowledge pertinent to their top science field (industrial R&D). Senior managers may work with trustees to create these channels to strengthen university–industry relationships to recruit trustees, to work with trustees to set research policy agendas that increase the flow of research funds from various sources, to gain insight from trustees with regard to research and financial investment, and to encourage trustees as donors. The channels that trustees create between universities and industry may deepen because trustees and senior management see them as mutually beneficial.

A surprising finding was the lack of significance of a medical school in 2005, in contrast to 1997 and to the literature generally, especially given the growth of NIH funding. This may be due to the increasing concentration of biotech and pharmaceuticals in Colleges of Pharmacy, in biosciences, or in centers or institutes devoted to discovery of technology or products that are central to health related businesses. These 2005 findings may anticipate academic based drug discovery centers that are now coming into play at universities in which corporations and universities invest jointly in discovery, with complex and varied funding arrangements (Blumenstyk, 2011).

However, in 2005 universities' corporate science fields, all else equal, were stronger predictors as measured by R&D dollars than any other variables commonly used to predict university success with regard to R&D. The change from 1997, when few variables were significant, to 2005 was swift. A number of factors may have contributed to this change: the growth of federal and state competitiveness policies in the 1990s and 2000s that sought to put academic science in the service of technology development and economic innovation; subsequent rapid increase in federal R&D funds in areas related to corporate science fields; the growing importance of national and international university rankings, to which success in research funding was increasingly salient (Marginson, 2007; Teichler, 2011).

Academic capitalism theorizes how segments of universities move toward the market. Our data suggest that networked trustees may constitute an emerging organizational field in which trustees who share research interests are an intermediating entity that shifts research universities in an entrepreneurial direction that is increasingly important to the management of university–industry science. We see these trustees as belonging to a different register than the channels thus far described in the literature (see related literature section, above). They may be engaged in research strategy at multiple levels. As directors of both universities and science based corporations, these relatively autonomous board members are in a unique position to influence the resourcing of discovery and innovation from the highest level of formal organizational authority. Trustees and senior managers may play a part in shaping national research policy to promote technology innovation and economic development, make investment decisions at universities that prioritize common areas of interest, explore new areas for future investment, and put industry funds into research areas likely to provide short-term payoff. The network may create trust that allows directors of science- based firms to pursue broad strategic goals that call for knowledge sharing and work on common problems such as shifting federal policy toward technology innovation and economic development. At the same time, trustees and senior managers at specific universities may pursue competitive advantages by treating their universities as firms that can maximize profits for both university and industry.

The AAU private university trustees network is executive in that its members are heads of corporations, members of boards of directors and trustees of universities: it is a network, not a club or executive committee, and is likely porous, informal, loosely coupled and one of many sets of players in the technology development and innovation game. For example, the boards of directors of foundations of public universities (which are distinct from their governmentally appointed boards of trustees or regents) seem to have members who have profiles similar to AAU private university trustees, and may have their own networks that engage in the same strategic knowledge management as private university trustees. Moreover, the private AAU trustees hold demanding executive positions that make it unlikely that they personally manage specific exchanges between their science corporations and the universities of which they are stewards, although they may bring areas of shared interest to the attention of corporate staff. Nonetheless, universities' corporate science fields, identified by trustee connections, all else equal, were stronger predictors as measured by R&D dollars than any other variables commonly used to predict university success with regard to R&D, and this suggests that the network is viable.

What calls for further exploration is how strategies and decisions flow through the network and this will require more research. For example, data could be expanded temporally, the importance of positions and paths within the network, as well as sub-networks, could be explored to see the effect they have on convergence and prediction of research funding or initiation of start-ups or other types of university–industry partnerships, patent profiles of network universities and trustees' corporations could be analyzed to see if universities and trustees' corporations are more likely to patent in the same areas over time (Slaughter et al., forthcoming). Data could be gathered on public university foundations to see if trustees of these organizations play similar roles to private AAU trustees. Perhaps most important for a full understanding of the strengths and weaknesses of the posited executive science network will be qualitative research that includes interviews with trustees of science corporations, other types of corporations and uninvolved trustees as well as with senior university managers, e.g., university presidents, vice-presidents for research, technology transfer managers. Only then are we likely to gain penetrating insight into how such a network functions and whether it has strategic purposes.

8. Conclusion

Whether private or public, American AAU research universities have trustees who operate with relative autonomy. Private university trustees have greater autonomy than public, in that they are neither appointed by state governors nor elected and are self-perpetuating, but public research university trustees or regents often serve as a buffer between institution and state and have the power to establish arms-length organizations, such as foundations, that can operate in a manner similar to private research universities, which technically, are also foundations. The autonomy of the private AAU research university boards may enable the trustees to constitute an executive science network that is important in securing research funding for universities. This in turn enables publications and patents. Trustees connections with industry likely contribute to university patenting, university–industry partnerships, technology development and economic innovation. Resources, publications and patents are all important to achieving world-class university status. It is not clear whether other countries should or could replicate the US trustee system. The European Union has declared its intent to best the US in terms of world-class university status and has encouraged its member nations to strengthen higher education (European Union, 2010). In recent years, a number of universities in the European nations have moved to appoint autonomous boards (Estermann and Nokkala, 2009; Estermann et al., 2011). Whether they will constitute executive science networks within their nations, and what such networks do remains to be seen.

Perhaps the biggest issue an executive science network faces is ICOI. The executive science network may precipitate new forms of institutional conflict of interest, particularly university as firm conflicts (Slaughter et al., 2009). These are the most recent type of ICOI and arise primarily when universities are involved in commercialization activity. For example, trustees' corporations have the potential to sponsor research at their university or to license university intellectual property or hold equity positions in spin-offs based on faculty research. In these transactions, trustees are economic actors making decisions simultaneously for their corporation and their university, treating both as firms by seeking to maximize revenues. While the economic goals of a trustee as member of a corporate board of directors and trustee of a university board member may often be the same—working to maximize discovery, technology development and economic innovation which return profits to the corporation and revenue to the university—there are occasions when the goals may diverge. For example, a trustees who also represents a corporate board may want to negotiate a lower license fee than a university trustee not representing the board would think appropriate. Or, trustees representing corporations with similar research interests may promote university investment in areas close to the corporate science fields they represent. Further, economic goals may conflict with research integrity or human subjects' protection requirements. For example, trustees could sit on the boards of directors of corporations that are running clinical trials at the university (Krimsky, 2003; Washburn, 2005). University as firm conflicts may also compromise academic values of openness and sharing of scientific information. Faculty and/or graduate students could be asked by firms on which trustees sit on the board of directors to withhold or delay publication while universities acquire patent rights to intellectual property (Slaughter et al., 2004). Trustees could prefer investment in STEM fields above all others, constraining growth and development of other fields.

To realize the potential of the executive science network to contribute to technology development and innovation, ICOI must be monitored and managed so as tap the synergy of the executive science network, yet not embroil universities in ethical or legal quandaries. AAU universities do have ICOI policies, but the degree to which they apply to trustees is often unclear (Slaughter et al., 2009). Yet potentially trustees may be involved in decisions about discrete aspects of technology development in research areas shared by their university and corporation(s). Such decisions are often lengthy, complex, have multiple decision points, and the nature and likelihood of conflict is often unclear. For example, university trustees acting as agents of the university as firm may have already patented and taken equity in a drug discovered by a faculty member before decisions are made about running clinical trials. Milestones may have to be reached, more university funds may need to be committed, and decisions about more research funding made before the process is complete, with each decision point raising the possibility of ICOI, especially if ICOI is considered as involving not only human subjects but research integrity and university values.

The theory of academic capitalism (Slaughter and Rhoades, 2004) suggests that trustees are likely to use their positions to further corporate as well as university interests, developing strategies that create infrastructure for corporate research interests, largely using public funds. Should that result in broad public benefit, such as economic recovery and income equality, policy makers who promote universities as engines of economic development may be justified; if the reverse is the case, then policy reformulation may be required. Perhaps the best way to monitor and manage ICOI would be to have a trans-university committee composed of trustees whose corporations are not actively involved in exchanges with their universities that have intellectual property potential. Such a committee would likely be knowledgeable about the network, and perhaps could monitor and provide guidance for managing these exchanges, and developing guiding policies and practices. This would address the Association of American Medical Colleges and the Association of American Universities (2008) concern that "[T]he existence (or appearance) of such [ICOI] conflicts can lead to actual bias, or suspicion about possible bias, in the review or conduct of research at the institution. If they are not evaluated or managed, they may result in choices or actions that are incongruent with the missions, obligations, or values of the university" (p. 1).

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Appendix A. A crosswalk between NAICS-CIP-field of science – Syracuse University 2005

Corporation	NAICS code	NAICS title	CIP code	CIP field	NSF field of science
Allstate Corp.	524126	Direct Property and Casualty Insurance Carriers	52	Business	Non-Science
Baker Hughes Inc.	333132	Oil and Gas Field Machinery and Equipment Manufacturing	40	Physical Sciences	Physical Sciences
Belmont Bancorp	522110	Commercial Banking	52	Business	Non-Science
Cintas Corp	315225	Men's and Boys' Cut and Sew Work Clothing Manufacturing	19	Family & Consumer Sciences/Human Sciences	Life Sciences
Consol Energy	212112	Bituminous Coal Underground Mining	40	Physical Sciences	Physical Sciences
Forest Laboratories Inc.	325412	Pharmaceutical Preparation Manufacturing	26	Biological & Biomedical Sciences	Life Sciences
Gardner Denver Inc.	333912	Air and Gas Compressor Manufacturing	14	Engineering	Engineering
Lennox International Inc.	333415	Air-Conditioning & Warm Air Heating Equipment Manufacturing	14	Engineering	Engineering
NBT Bancorp	522110	Commercial Banking	52	Business	Non-Science
Nipsource Inc	22111	Electric Power Generation	14	Engineering	Engineering
Paetec Holding Co.	517110	Wired Telecommunications Carriers	09	Communication and Journalism	Non-Science
Radio One Inc.	515112	Radio Stations	09	Communication and Journalism	Non-Science

References

Academic Rankings of World Universities, 2012. Downloaded July 2012 from http://www.shanghairanking.com/ARWU2012.html
Ahn, C., Eisenberg, P., Khamvongsa, C., 2003. Foundation and Trustee Fees. The Center for Public and Nonprofit Leadership, Georgetown Public Policy Institute, Georgetown University, Washington, DC.
Alchian, A., Demsetz, H., 1972. Production, information costs, and economic organizations. American Economic Review 62 (December), 777–795.
Altbach, P., 2007. The costs and benefits of world-class universities. In: Sadlak, J., Cai, L.N. (Eds.), The World-class University and Ranking: Aiming Beyond Status. UNESCO-CEPES. Cluj-Napoca: Presa Universitara Clujeana, Bucharest, pp. 363–370.
Association of American Medical Colleges, Association of American Universities, 2008. Protecting patients, preserving integrity, advancing health: accelerating the implementation of COI policies in human subjects research. Downloaded April 2009 from http://www.aau.edu/publications/reports.aspx
Association of Governing Boards, 2007. The Independent Board's Responsibilities. Association of Governing Boards, Washington, DC. Downloaded October 2007 from http://www.agb.org/wmspage.cfm?parm1=331
Bartlett, E., 2008. International analysis of institutional review boards registered with the U.S. Office for Human Research Protections. Journal of Empirical Research on Human Research Ethics 3 (4), 49–56.
Beattie, A., 2011. Market crashes: the dotcom crash, Downloaded October 2011 from http://www.investopedia.com/features/crashes/crashes8.asp#axzz1mqDhuxf9
Baskin, P., 2011. NIH pushes ahead on research division to speed drug development, despite protests from scientists and others. February 23. Chronicle of Higher Education. Downloaded February 2011 from http://chronicle.com/article/NIH-Pushes-Ahead-on-Research/126500/
Beck, H., 1947. Men Who Control our Universities: The Economic and Social Composition of Governing Boards of Thirty Leading American Universities. Kings Crown Press, New York.
Bekelman, J., Li, Y., Gross, C.P., 2003. Scope and impact of financial conflicts of interest in biomedical research: a systematic review. Journal of American Medical Association 289 (4), 454–465.
Bekkers, R., Freitas, I., 2008. Analysing knowledge transfer channels between universities and industry: to what degree do sectors also matter? Research Policy 37, 1837–1853.
Bercovitz, J., Feldman, M., 2007. Fishing upstream: firm innovation strategy and university research alliances. Research Policy 36, 930–948.
Bercovitz, J., Feldman, M., 2011. The mechanisms of collaboration in inventive teams: composition, social networks, and geography. Research Policy 40, 81–93.
Blumenstyk, G., 2011. Big Pharma finds a home on campus. Chronicle of Higher Education (July), 2011.
Bowen, H., 1980. The Costs of Higher Education: How Much Colleges and Universities Spend Per Student and How Much Should They Spend? Jossey-Bass Publishers, San Francisco.
Boyd, E.A., Lipton, S., Bero, L.A., 2004. Implementation of financial disclosure policies to manage conflicts of interests: how seven University of California campuses deal with their research relationships. Health Affairs 23 (2), 206–214.
Bruneel, J., D'Este, P., Salter, A., 2010. Investigating factors that diminish the barriers to university–industry collaboration. Research Policy 39, 858–868.
Burt, R.S., 1983. Corporate Profits and Cooptation. Academic Press, New York.
Campbell, E., Weissman, J., Ehringhaus, S., Rao, S., Moy, B., Feibelmann, S., Gold, S., 2007. Institutional academic–industry relationships. Journal of the America Medical Association 298 (15), 1779–1786.
Campbell, E., Weissman, J., Vogeli, C., Clarridge, B., Abraham, M., Marder, J., Koski, G., 2006. Financial relationships between institutional review board members and industry. New England Journal of Medicine 355 (22), 2321–2329.
Cantwell, B., Mathies, C., 2012. Expanding research capacity at United States universities: a study of academic research and development investment from 1990–2005. Higher Education Quarterly 66 (3), 308–330.
Chait, R., Holland, T., Taylor, B., 1991. The Effective Board of Trustees. MacMillan Publishing, New York.
Cho, M., Shohara, R., Schissel, A., Rennie, D., 2000. Policies on faculty conflict of interest at U.S universities. Journal of American Medical Association 284 (17), 2203–2208.
Choo, C., Bontis, N., 2002. The Strategic Management of Intellectual Capital and Organizational Knowledge. Oxford University Press, New York.
Colyvas, J., 2007. From divergent meanings to common practices: the early institutionalization of technology transfer in the life sciences at Stanford University. Research Policy 36, 456–457.
Davis, G., 1991. Agents without principles? The spread of the poison pill through the intercorporate network. Administrative Science Quarterly 36 (4), 583–613.
Dehon, C., McCathie, A., Veradi, V., 2011. Uncovering excellence in academic rankings: a case study on the Shanghai ranking. Scientometrics 83 (2), 515–524.
D'Amato, T., Gilroy, L., Bassett, P., 2010. The patent scorecard 2010—universities. Intellectual Property Today. Downloaded July 2011. http://www.iptoday.com/issues/2010/09/the-patent-scorecard-2010-universities-.asp
D'Este, P., Patel, P., 2007. University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry? Research Policy 36, 1259–1313.
DiMaggio, P., Powell, W., 1983. The iron cage revisited: institutional isomorphism and collective rationality in organizational fields. American Sociological Review 48 (2), 147–160.
Domhoff, G., Dye, T., 1987. Power Elites and Organizations. Sage Publications, Newbury Park, NJ.
Dye, T., 1989. Who's Running America? The Bush Era, 5th edition. Prentice Hall, Upper Saddle River, NJ.
Dye, T., 1994. Who's Running America? The Clinton Years, 6th edition. Prentice Hall, Upper Saddle River, NJ.
Dye, T., 2002. Who's Running America? The Bush Restoration, 7th edition. Prentice Hall, Upper Saddle River, NJ.
Estermann, T., Nokkala, T., 2009. University Autonomy in Europe 1: Exploratory Study. European University Association, Brussels, Belgium.
Estermann, T., Nokkala, T., Stienel, M., 2011. University Autonomy in Europe II: The Scorecard. European University Association, Brussels, Belgium.
European Commission, 2010. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Europe 2020 Flagship Initiative. Innovation Union, Brussels, Belgium 6.10.2010COM(2010) 546 final.
Fama, E., 1980. Agency problems and the theory of the firm. Journal of Political Economy 88 (2), 288–307.
Feller, I., 1996. The determinants of research competiveness among universities. In: Teich, A. (Ed.), Competitiveness in Academic Research. Committee on Science, Engineering, and Public Policy. American Association for the Advancement of Science, Washington, DC, pp. 35–72.
Fontana, R., Geuna, A., Matt, M., 2006. Factors affecting-university industry R&D projects: the importance of searching, screening and signaling. Research Policy 35, 309–323.
Geiger, R., 1996. Making the grade: institutional enhancement of research competitiveness. In: Teich, A. (Ed.), Competitiveness in Academic Research. Committee on Science, Engineering, and Public Policy. American Association for the Advancement of Science, Washington, DC, pp. 113–136.
Geiger, R., 2004. Knowledge and Money: Research Universities and the Paradox of the Marketplace. Stanford University Press, Stanford, CA.
Ghoshal, S., Nohria, N., 1993. Horses for courses: organizational forms for multinational corporations. Sloan Management Review 34 (Winter (2)), 23–35.
Goldschmidt, N., Finkelstein, J., 2001. Academics on board: university presidents as corporate directors. Academe: Bulletin of the American Association of University Professors (September–October), 33–37.
Granovetter, M., 1973. The strength of weak ties. American Journal of Sociology 78 (6), 1360–1380.

Haunschild, P., Beckman, C., 1998. When do interlocks matter? Alternate sources of information and interlock influence. Administrative Science Quarterly 43 (4), 815–844.
Hill, B., Green, M., Eckel, P., 2001. What governing boards need to know and do about institutional change. In: Project on Leadership and Institutional Transformation. American Council on Education, Washington, DC.
Huizing, A., Bouman, W., 2002. Knowledge and learning, markets and organizations: managing the information transaction space. In: Choo, C.W., Bontis, N. (Eds.), The Strategic Management of Intellectual Capital and Organizational Knowledge. Oxford University Press, New York, pp. 185–204.
Kerr, C., Gade, M., 1989. The Guardians: Boards of Trustees of American Colleges and Universities. Association of Governing Boards, Washington.
Krimsky, S., 2003. Science in the Private Interest: Has the Lure of Profits Corrupted Biomedical Research? Rowman & Littlefield, Lanham, MD.
Lam, A., 2007. Knowledge networks and careers: academic scientists in industry–university lines. Journal of Management Studies 44 (6), 993–1016.
Laursen, K., Salter, A., 2004. Searching high and low: what types of firms use universities as a source of innovation. Research Policy 33, 1201–1215.
Madsen, H., 1997. Composition of governing boards of public colleges and universities. AGB Occasional Paper Number 37. Association of Governing Boards of Universities and Colleges, Washington, DC.
Marginson, S., 2007. Global university rankings: where to from here. Downloaded October 2011 from http://www.cshe.unimelb.edu.au/people/marginson_docs/APAIE_090307_Marginson.pdf
Mathies, C., 2010. Research hierarchy: the relationship among university characteristics and federal funding. Unpublished doctoral dissertation. University of Georgia, Athens, GA.
Mizruchi, M., 1996. What do interlocks do? Analysis, critique, and assessment of research on interlocking directorates. Annual Review of Sociology 22, 271–298.
Mueller, P., 2006. Exploring the knowledge filter: how entrepreneurship and university–industry relationships drive economic growth. Research Policy 35, 1499–1508.
Nahapiet, J., Ghoshal, S., 1998. Social capital, intellectual capital, and the organizational advantage. The Academy of Management Review 23 (2), 242–266.
National Center for Educational Statistics, 2009. Integrated Postsecondary Education Data System (IPEDS). US Department of Education, Washington, DC. Downloaded October 2009 from http://nces.ed.gov/ipeds/datacenter/
National Center for Educational Statistics, 2010. Classification of Instructional Programs (CIP 2000). US Department of Education, Washington, DC. Downloaded December 2010 from http://nces.ed.gov/pubs2002/cip2000/
National Economic Council, Council of Economic Advisors, Office of Science and Technology Policy, 2011. A Strategy for American Innovation: Securing Our Economic Growth and Prosperity. The White House, Washington, DC.
National Institute for Health, 2011. NIH Fact Sheet. Downloaded August 2011 from https://www.aamc.org/research/adhocgp/081011.pdf
National Science Board, 2010. Science and Engineering Indicators 2010. National Science Foundation, Arlington, VA.
National Science Board, 2012. Science and Engineering Indicators 2012. National Science Foundation (NSB 12-01), Arlington, VA.
National Science Foundation, 2007. Survey of Research and Development Expenditures at Universities and Colleges. Division of Science Resources Statistics. Research expenditures data downloaded April/May 2006 and May 2007 via Webcaspar system from http://webcaspar.nsf.gov/
National Science Foundation, 2010. Survey of Research and Development Expenditures at Universities and Colleges. Division of Science Resources Statistics. Questionnaire form downloaded August 2010 from http://www.nsf.gov/statistics/srvyrdexpenditures/surveys/srvyrdenditures_2009.pdf
Nicholson-Crotty, J., Meier, K., 2003. Politics, structure and public policy: the case of higher education. Educational Policy 17 (1), 80–98.
Orszag, P., Holdren, J., 2009. Memorandum for the Heads of Executive Departments: Science and Technology Priorities for the FY 2011 Budget. The White House, Washington, DC.
Pfeffer, J., Salancik, G., 1978. The External Control of Organizations: A Resource Dependence Perspective. Harper and Row, New York.
Pusser, B., 2004. Burning Down the House: Politics, Governance, and Affirmative Action at the University of California. SUNY Press, Albany, NY.
Pusser, B., Slaughter, S., Thomas, S., 2006. Playing the board game: an empirical analysis of university trustee and corporate board interlocks. Journal of Higher Education 77 (5), 747–775.
Reeser, J., Austin, D., Jaros, L., Mukesh, B., McCarty, C., 2008. Investigating perceived institutional review board quality and function using the IRB research assessment tool. Journal of Empirical Research on Human Research Ethics 3 (1), 25–34.
Saisana, M., d'Hombres, B., Saltelli, A., 2011. Rickety numbers: volatility of university rankings and policy implications. Research Policy 40, 165–177.
Salter, A., Martin, B., 2001. The economic benefits of publicly funded research: a critical review. Research Policy 30, 509–532.
Sampat, B., Lichtenberg, F., 2011. What area the respective roles of the public and private sector in pharmaceutical innovation? Health Affairs 30 (2), 332–339.
Savage, J., 1999. Funding Science in America: Congress, Universities, and the Politics of Academic Pork Barrel. Cambridge University Press, Cambridge, UK.
Selznick, P., 1957. Leadership in Administration. Harper and Row, New York.
Shinn, T., Lamy, E., 2006. Paths of commercial knowledge: forms and consequences of university–enterprise synergy in scientist-sponsored firms. Research Policy 35, 1465–1476.
Sinclair, U., 1923. The Goosestep, A Study of American Education. Author, Pasadena, CA.
Slaughter, S., 1990. The Higher Learning and High Technology: The Dynamics of Higher Education Policy Formation. SUNY Press, Albany, NY.
Slaughter, S., Archerd, C.J., Campbell, T.I.D., 2004. Boundaries and quandaries: how professors negotiate market relations. Review of Higher Education 28 (1), 129–165.
Slaughter, S., Cantwell, B., 2012. Transatlantic moves to the market: academic capitalism in the US & EU. Higher Education 65 (5), 583–606.
Slaughter, S., Feldman, M., Thomas, S., 2009. Policies on institutional conflict of interest at US research universities. Journal of Empirical Research on Human Ethics Research 4 (3), 3–18.
Slaughter, S., Leslie, L., 1997. Academic Capitalism: Politics, Policies and the Entrepreneurial University. Johns Hopkins University Press, Baltimore, MD.
Slaughter, S., Rhoades, G., 1996. The emergence of a competitiveness research and development policy coalition and the commercialization of academic science and technology. Science, Technology, and Human Values 21 (3), 303–339.
Slaughter, S., Rhoades, G., 2004. Academic Capitalism and the New Economy: Markets, State and Higher Education. Johns Hopkins University Press, Baltimore, MD.
Slaughter, S., Rhoades, G., 2005. From endless frontier to basic science for use: social contracts between science and society. Science, Technology, and Human Values 30 (4), 1–37.
Slaughter, S., Thomas, S., Johnson, D., Barringer, S. Private research university trustees, shared university and corporate patent classes and conflict of interest. Journal of Higher Education, forthcoming, accepted 3/18/2013.
Stearns, L., Mizruchi, M., 1993. Board composition and corporate financing: the impact of financial institution representation on borrowing. The Academy of Management Journal 36 (3), 603–618.
Stephan, P., 2012. How Economics Shapes Science. Harvard University Press, Cambridge, MA.
Stuart, T., Salih, O., Ding, W., 2007. Vertical alliance network: the case of university–biotechnology–pharmaceutical alliance chains. Research Policy 36, 477–499.
Suresh, S., 2011. Talking Points on the National Science Foundation's Innovation Corps to Strengthen the Impact of Scientific Discoveries. July 28. National Science Founding, Washington, DC.
Teich, A., Gramp, K., 1996. Making the grade: institutional enhancement of research competiveness. In: Teich, A. (Ed.), Competitiveness in Academic Research. Committee on Science, Engineering, and Public Policy. American Association for the Advancement of Science, Washington, DC, pp. 73–111.
Teichler, U., 2011. Social contexts and systemic consequences of university rankings: a meta-analysis of the rankings literature. University rankings. The changing academy. The Changing Academic Profession in International Comparative Perspective 3 (Part 1), 55–69.
The Economist, May 19, 2012. The endangered public company. Downloaded July 2012 from http://www.economist.com/node/21555552
Toole, A., 2011. The impact of public basic research on industrial innovation: evidence from the pharmaceutical industry. Research Policy 41, 1–12.
United Nations Millennium Project, 2005. Innovation: Applying Knowledge in Development. Task Force on Science, Technology, and Innovation. United Nations Development Programme, NY.
United States Census Bureau, 2010. North American Industry Classification System. U.S. Census Bureau, Washington, DC. Downloaded January 2010 from http://www.census.gov/eos/www/naics/
Useem, M., 1984. The Inner Circle. Oxford University Press, New York.
Varma, R., Worthington, R., 1995. Immiseration of industrial scientists in corporate laboratories in the United States. Minerva 33 (4), 325–338.
Van McCrary, S., Anderson, C., Jakovljevic, J., Khan, T., McCullough, L., Wray, N., Brody, B., 2000. A national survey of policies on disclosure of conflicts of interest in biomedical research. New England Journal of Medicine 343 (22), 1621–1626.
Veblen, T., 1918. The Higher Learning in America: A Memorandum on the Conduct of Universities by Business Men. B.W. Huebsch, New York.
Washburn, J., 2005. University Inc.: The Corporate Corruption of Higher Education. Basic Books, NY.
Weinstein, A., 2010. The dot-com crash, 10 years on. Mother Jones, Downloaded March 10, 2012 from http://www.motherjones.com/mojo/2010/03/dot-com-crash-10-year-anniversary-recession-crisis-subprime-mortgage-hubris
Weissman, J., Koski, G., Vogeli, C., Thiessen, C., Campbell, E., 2008. Opinions of IRB members and chairs regarding investigators' relationships with industry. Journal of Empirical Research on Human Research Ethics 3 (1), 3–14.
Welsh, R., Glenna, L., Lacy, W., Biscotti, D., 2008. Close enough but not too far: assessing the effects of university–industry research relationships and the rise of academic capitalism. Research Policy 37, 1854–1864.
Westphal, J., Seidel, M., Stewart, K., 2001. Second-order imitation: uncovering latent effects of board network ties. Administrative Science Quarterly 46 (4), 717–747.
Wing, K., Roeger, K., Pollack, T., 2009. The Nonprofit Sector in brief. Public Charities, Giving and Volunteering. Urban Institute, Washington, DC.
Wolf, L.E., Catania, J.A., Dolcini, M.M., Pollack, L.M., Lo, B., 2008. IRB chairs' perspectives on genomics research involving stored biological materials: ethical concerns and proposed solutions. Journal of Empirical Research on Human Research Ethics 3 (4), 99–112.
World Bank Institute, 2007. Building knowledge economies: advanced strategies for development. In: Knowledge for Development Program. The World Bank, Washington, DC.

Zajac, E., 1988. Interlocking directorates as an interorganizational strategy: a test of critical assumptions. The Academy of Management Journal 31 (2), 428–438.

Zucker, L., Darby, M., 1996. Star scientists and institutional transformation: patterns of invention and innovation in the formation of the biotechnology industry. Proceedings of the National Academy of Sciences 93 (November (23)), 12709–12716.

Zucker, L., Darby, M., 2007. Star scientists, innovation, regional and national immigration. Paper Prepared for Presentation at the Second Annual Kauffman Foundation/Max Planck Institute Research Conference on Entrepreneurship, July 19–21. Downloaded December 2010 from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1001112