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Cacophony or harmony? Multivocal logics and technology licensing by the Stanford University Department of Music

Andrew J. Nelson

This paper explores the rise and role of technical and commercial logics within the Stanford University music department. I examine the initial framing of these novel activities in terms of musical composition, and the subsequent interaction between technical, commercial and musical logics over a thirty-year period. Ultimately, positive feedbacks between the various logics have led to a mutual dependence, solidifying the centrality of musical composition within the department while underscoring the complementary role of technical and commercial endeavors.

1. Introduction

Patenting and licensing of university research is a topic that has merited considerable recent attention from scholars. The questions surrounding such activity are multifold. One strand of research focuses on the role of intellectual property rights and technology licensing offices in bringing university research into practice (Colyvas *et al.*, 2002). Related work discusses the effect of organizational practices and university policies on the productivity of technology transfer offices, including their creation of startups (Di Gregorio and Shane, 2003; Siegel *et al.*, 2003). In a comparison of the United States and Sweden, Goldfarb and Henrekson (2003) consider national policies and their role in promoting the commercialization of university-generated knowledge.

A major stream of research focuses on the influence of federal policy. Clearly, the passage of the Bayh–Dole Act of 1980, which allowed universities to hold the intellectual property rights for technologies developed with federal research dollars, coincided with an increase in patenting and licensing of university research (Eisenberg, 1996; Mowery *et al.*, 2001). Studies of pre-Bayh–Dole commercialization activities remind us, however, of the historical context and precedents to this trend (Mowery and Sampat, 2001a, b).

Scholars are also concerned with the effects of university patenting and licensing on subsequent research orientations by university researchers (Mowery *et al.*, 2001). For example, Henderson *et al.* (1998) find that while the volume of US university patents increased following Bayh–Dole, the importance and generality of patents declined.

They argue that this could result from a shift in universities' internal research cultures, or it could reflect the post-1980 entry of new institutions that are less skilled in patenting. Mowery and colleagues (Mowery and Zeidonis, 2002; Mowery *et al.*, 2002) find evidence for the latter: new entrants are initially less skilled in their patenting activities, suggesting that there is a learning process that takes place. Owen-Smith and Powell (2003) reinforce this view, and present evidence that network ties to industry enable institutions to develop higher impact patent portfolios, but that learned experience is necessary to manage these ties effectively.

Other studies focus attention on the impact of university patenting and licensing activity on industry. The role of university research in supporting technical advances in industry is well documented (Nelson, 1986; Jaffe, 1989; Rosenberg and Nelson, 1994). Recent studies suggest that the importance of university research is growing and identify a particular role for licenses in this transfer process (McMillan *et al.*, 2000; Hicks *et al.*, 2001).

A common thread through much of this work on university patenting and licensing is the view that academic and commercial pursuits represent different logics (Heller and Eisenberg, 1998; Henderson *et al.*, 1998; Powell and Owen-Smith, 1998; Campbell *et al.*, 2000; Rai and Eisenberg, 2003). That is, they may differ in goals, practices and even symbolic constructions (Friedland and Alford, 1991). One example of differing logics may be found in Dasgupta and David's (1987, 1994) observations about the reward structures that separate the realms of science and technology. In science, practitioners strive to be the first to publish. Open publication encourages subsequent use by others and scientists are rewarded by the prestige that comes from this use (Merton, 1957, 1968). In technology, the rewards are pecuniary. Technologists are concerned with economic rents that can be earned from the application of knowledge and they display more reticence in publishing their findings.

In the life sciences, Powell and Owen-Smith (1998) argue that this separation of the realms of science and technology no longer holds. Building on this finding, Owen-Smith (2003) posits that a 'hybrid institutional system' composed of commercial and academic standards may lead to positive feedback loops between public and private uses of science. Simultaneously, new standards stand to alter work practices and relationships on university campuses, along with evaluations of success and allocation of rewards (Owen-Smith and Powell, 2001). Moreover, conflicts may emerge between these logics (Powell and Owen-Smith, 1998).

In Friedland and Alford's (1991) conception, conflicting logics may lead to a variety of outcomes. The outcome actually realized depends upon individual agency and is influenced by the extent to which institutionally specific roles affect the resources available to proponents of each logic. By better understanding how multiple logics may be manipulated by individuals and how the results of this manipulation may themselves become institutionalized in the 'hybrid form', we can better understand the nature of institutional changes surrounding university technology licensing and the limits upon such changes.

Towards this goal, this article considers the history of the Stanford University music department to explore how two logics—a musical focus and an attention to technical development—have shaped one another over time. The case of the Stanford music department is an important contribution to the literature on university-commercial activities for several reasons: First, it provides an understanding of one of the earliest licenses (FM sound synthesis) from one of the first universities to become involved in commercialization activities. Second, FM synthesis was Stanford's first 'home run' and continues to hold a spot as one of the university's top revenue-producing licenses. Third, the historical approach provides a richly detailed account of the growth of commercial ties in the music department from a single license to a broad portfolio of licenses, industry affiliates and a trademark program. Finally, the setting is novel and relays the experience of a group in the humanities whose concerns, it would seem, would be far removed from technology development and industry relations. This final point is a critical one; in so far as the issues and challenges surrounding university technology licensing find their basis in the differing logics, it would seem vital to explore those cases where the logics would in fact have very little—seemingly—in common. The novel setting also provides an example of the extent to which commercial logics may pervade universities. Since Stanford's music department is an early example, it is not the case that what started in other spheres is finally spilling over into the humanities. Rather, the example serves to illustrate that commercial logics may be compelling—even early on—in spheres beyond engineering and medicine, and it encourages examination of such unexpected cases as a means to highlight potential synergies and conflicts between different logics.

The particular details presented illustrate how the Stanford music department's technology development activity began outside of 'normal channels' and how the surrounding institutional context developed in such a way that FM sound synthesis, Stanford's first commercial success, was not a 'one-hit wonder'. Central to the account is the use of an existing organizational logic, that of composition, to spawn a novel logic of technological development and commercial relations. The pattern of interaction between these logics, presented over a thirty-year period, highlights numerous reinforcing feedbacks that have led to a mutual dependence, both solidifying the centrality of composition and underscoring the role of technology development and commercial relations within the music department.

2. Methods

The historical materials presented here are assembled from a variety of sources. I interviewed key faculty in the music department, familiar with the history of the department and active in its current administration, and personnel in Stanford's Office of Technology Licensing who work with the music and sound technologies developed at Stanford. These accounts were supplemented with transcripts of several interviews conducted by others.[1] I also reviewed two major archival sources. The archives of Stanford's Office of Technology Licensing contain invention disclosures, funding arrangements, correspondence between relevant participants, grant applications, marketing materials and strategic plans. The Stanford University archives hold documents of the Board of Trustees, financial records on the funding of the music department and computer music group, personal notes of department administrators, internal memos, photographs, past issues of the music department newsletter, and several private letters between various individuals including faculty, administrators and industry contacts. I systematically combed these materials to assemble all the available documents on the music department's technical and commercial activities.

The Stanford University Development Office was a source for the financial transaction records between relevant companies and the university. From the Stanford University Office of the Registrar, I obtained information on music students' dates of affiliation and status. Armed with these lists, I accessed the United States Patent and Trademark Office database to obtain comprehensive records of all patents filed by and granted to affiliated music department personnel. In addition, Stanford's computer music group publishes a semi-regular annual report, which provided information on each year's research, affiliated faculty and students, and sources of support. Finally, I consulted several popular press articles on various aspects of the case to assess the consistency of the story suggested by interviews, quantitative data and archival materials.

3. Stanford's music department and 'CCRMA'

Stanford University opened on 1 October 1891, the product of Jane and Leland Stanford's vision to build a major West Coast university. From the beginning, the Stanfords' vision for the university included plans for 'a grand conservatory of music, under the direction of the most famous masters of Italy and Europe which will afford the best musical education to be had in the world' (Schmidt, 1991: 1). The Stanfords' model was a European one, and never included the integration of musical studies into other courses. Ultimately, due to funding shortages, the vision was never fulfilled during the Stanfords' lifetime.

Informal musical activities continued on campus and their formal incorporation in the curriculum and administration was occasionally pondered, as evidenced by an internal memo from then-President Ray Lyman Wilbur to the Board of Trustees in 1926. The memo discusses the possible formation of 'an adequate School of Music along the lines of the Yale School of Music', but no further action was taken. But, in

[1]John Chowning, a central character in the account, provided a thorough interview as part of the Yale University Oral History Project (Chowning, 1983). Shorter interviews appeared in popular press articles.

the 1930s, American educator and composer Randall Thompson, supported by the Carnegie Foundation, ran a study to determine the extent to which musical education was an essential component of education as a whole. The study was influential across the country in encouraging the integration of musical studies with other disciplines. Although Stanford was not one of the universities surveyed, university officials clearly noticed the study, and its release coincided with the formation of the Friends of Music at Stanford and a rise in the place of music in the university (Schmidt, 1991). From 1934 to 1946, students could minor in music through the School of Humanities, or they could obtain a teaching credential in music through the School of Education. The Division of Music finally became a department in 1946, marking Stanford as one of the last major universities to establish a music department (Tanner, 1978).

In 1962, John Chowning arrived at Stanford as a doctoral student in music. Though a friend familiar with UC Berkeley's music program encouraged him to attend there instead, Chowning recalled, 'There was a little more money in the Stanford grant than Cal's. So we came here' (Chowning, 1983: 9). Chowning had been exposed to electronic music while studying composition in Paris. Upon arrival at Stanford, he inquired as to the possibility of electronic music, finding, 'There was no studio, and certainly no interest' (Bailie, 1982). Chowning grew discouraged and considered finishing a masters degree and dropping out of the Ph.D. program (Chowning, 1983).

In 1963, Chowning read a *Science* article on computer sound synthesis written by Max Mathews of Bell Labs. He took a computer-programming course that spring and went to visit Mathews in the summer. Mathews pointed Chowning towards further reading and agreed to send his Music IV computer program. Chowning looked around campus and found that the Artificial Intelligence project had acquired a DEC PDP-1 computer. Since Mathews' program was written for an IBM 7090 computer, Chowning enlisted the help of David Poole, a Stanford undergraduate skilled in computer programming. Poole was also a tuba player, and Chowning played timpani and sat next to him in the Stanford symphony. Poole wrote a compiler for the PDP-1 and they made their first sound in September 1964 (Stanford Department of Music, 1982; Chowning, 1983).[2]

Chowning became the student of Leland Smith, a Stanford music professor, in 1964 and proposed to study computer sound synthesis as his thesis topic. Smith later remembered, 'I told him that I didn't know anything about it and that he could go ahead just as long as he would teach me' (Weiss, 1980). In 1966, Chowning received his DMA in composition, joined the faculty of the Stanford Music Department, and continued his work in computer music through the Artificial Intelligence (AI) Laboratory. As Chowning recalled, 'We needed to use their facilities, so we became rather tenacious parasites. Leland and I had one room up there, and worked mostly at night and on weekends so as not to abuse our hosts' (Stanford Department of Music, 1982).

[2]Mathews continues to play an important role at CCRMA. Upon his retirement from Bell Laboratories in the early 1990s, he joined the music department as a research professor and is still active.

Still, there was tension between the groups as the AI group (which had funding from ARPA) blamed the non-funded music group for various problems. By this point, however, Poole was an indispensable employee of the AI lab due to his programming abilities. Poole's advocacy and support from AI administrator Les Ernest, whose wife taught music, protected the music group (Chowning, 1983).

Chowning had a major breakthrough in 1968 when he developed frequency modulation (FM) synthesis, which uses one waveform to modify a second waveform in order to produce complex and varied sounds with relatively few computations. The discovery resulted not from theory-driven science, but from late-night experimentation. As Chowning recalled,

> Well, what happened is, I was fooling around with vibrato—very, very wide vibrato—one day... and I noticed that I was not—at some moment I was no longer tracking pitch, but I was hearing these timbral changes... and kind of observed that sometimes it would be more or less harmonic, and other times seemed dissonant. (Chowning, 1983: 23–24)

Chowning spent years playing with parameters, reviewing engineering texts and holding discussions with colleagues in engineering, mathematics, computer science and music. Ultimately, it was apparent that the technique could facilitate the creation of radically new sounds and could allow unprecedented control over these sounds. (FM synthesis sounds would eventually feature prominently in nearly every pop music hit of the 1980s. Think of Madonna and Phil Collins as exemplars.)

In 1970, conversations between Chowning, Mathews and Neils Reimers, director of Stanford's just-formed Office of Technology Licensing (OTL), suggested that there could be commercial interest in the technology. Reimers approached the obvious companies: major domestic organ manufacturers.[3] But, between 1971 and 1975 no US company was interested in the technology. For those few that understood the technique, it was considered too difficult, impossible to reasonably price, and too intensive in terms of memory, computation, resources and time (Darter, 1985; Garman and Kosnik, 1998).

In 1973, Stanford denied Chowning tenure. But, later that year when Albert Cohen arrived at Stanford as the new music department chair, he felt that this denial was a clear mistake. (Cohen had taught at University of Michigan and chaired the music department at SUNY/Buffalo prior to coming to Stanford. At both universities, electronic music studios were important to the composition programs.) Cohen's feelings were confirmed by an invitation that Chowning received: Pierre Boulez, world-renowned composer and then-conductor of the New York Philharmonic and the BBC Symphony Orchestra, asked him to plan a large electronic music center in France.

[3] See Pinch (2002) for an important account of how sound synthesis came to be coupled with the musical keyboard interface, a connection that Reimers clearly had in mind in approaching organ manufacturers.

Cohen urged Chowning to return to Stanford to appeal his tenure case and the new dean of the School of Humanities and Sciences provided a temporary adjunct professorship while the appeal was arranged.

Upon Chowning's return, Stanford formed the Center for Computer Research in Music and Acoustics (CCRMA), largely as an administrative move to support a $600 000 grant proposal that Chowning and Smith made jointly to the National Science Foundation (NSF) and the National Endowment for the Arts (NEA). Still, there was no existing funding for computer music and Chowning's tenure case was unresolved (Chowning, 1983). As Cohen noted that year, 'The program is in a state of flux' (Flynn, 1974).

In 1975, the music department received two crucial grants. The NSF awarded $254 600 under the field of Computer Research–Computer Application in Research for research in computer music. This was the first grant that the NSF had ever awarded to a music department, and it was the largest grant that year in this subcategory of 64 and the third largest of the 190 grants in the overall category of Computer Research. Chowning and Smith were co-principle investigators (NSF, 1975). That same year, the NEA awarded $160 000 for the purchase of computer equipment, the largest of the 29 grants that year awarded under the category of Special Music Programs, representing more than 15% of total money awarded in the category (NEA, 1975). The joint NSF–NEA funding for the project—possibly the first of its kind—is itself indicative of early multivocality between musical and technical logics.

Also in 1975, Chowning and OTL director Neils Reimers finally found a licensing opportunity for FM synthesis. Reimers had put a Stanford business school student on the case, who had learned that Yamaha was the world's largest manufacturer of musical instruments—a surprising finding since they had little US market share. Reimers contacted Yamaha in Japan and it so happened that they had one of their chief engineers visiting the Los Angeles Yamaha office. The engineer, Kazukiyo Ishimura, traveled to Stanford for a day and immediately understood the potential of the technology. Ishimura became Yamaha's internal advocate for the technology and argued that the company should take out the license (Darter, 1985; Garman and Kosnik, 1998).

The near-term commercial viability of FM synthesis was anything but given. Indeed, the first realization of Chowning's design required nearly 40 integrated circuit chips—a very expensive proposition. Thus, Yamaha would not only be licensing an algorithm, but also committing to an extended period of product research and development. Yamaha had already been experimenting with digital synthesis, however, and was well equipped for the challenge. Stanford offered Yamaha an exclusive license to protect the considerable investment that would be required and Chowning embarked on a pattern of frequent visits to collaborate with Yamaha engineers in developing the technology.

In 1983, Yamaha released the first of the DX series of synthesizers, the largest selling single set of musical instruments ever made. Ishimura went on to become President of

Yamaha Corporation in 1997 and Stanford ultimately earned nearly $23 m. from the license (Garman and Kosnik, 1998; OTL financial records).

Stanford appointed Chowning full professor of music in 1978, largely due to his development of the computer music program (Stanford Department of Music, 1979). The following year, the AI lab moved to join the building that housed the computer science department. The AI group officially separated itself from CCRMA, forcing the latter to become independent and to find another computer system. There was a funding shortage, however, and it was difficult to purchase a computer. Not coincidentally, CCRMA turned to David Poole, who as an undergraduate had helped Chowning with Mathews' computer music program. Poole had later developed the concept of cache memory and founded Foonly Corporation to build on these ideas. Stanford drew on many and varied sources of support to acquire a Foonly F2 computer and to renovate the building that CCRMA had shared with the AI lab. These sources included Poole and the NEA grant, as well as an advance on royalties from Yamaha, gifts from a local benefactor and a loan from the School of Humanities and Sciences (Stanford Department of Music, 1982; Chowning, 1983; Chafe, 2002).

Between 1975 and 1982, the NSF awarded CCRMA over $1 m. in grants. In 1982, the System Development Foundation awarded CCRMA a $300 000 grant to upgrade its computer system and a five-year $2.3 m. grant to support ongoing work (Stanford Department of Music, 1982). At the same time, the flow of royalties from FM synthesis increased. The grants covered operating expenses and allowed much of these royalties, and royalties from other CCRMA inventions, to be placed in an endowment. After the music department moved to a new facility in 1984, CCRMA renovated the previous music department facility and assumed occupancy (Stanford Department of Music, 1984).

CCRMA has served as a model for other centers in the United States and abroad. CCRMA personnel have established similar centers throughout the world, and researchers and musicians are frequent visitors to the Stanford site (CCRMA *Overview*, various years; Weiss, 1980). Further, FM synthesis was just the first in a long series of inventions with their roots in CCRMA. Figure 1 conveys patent data for CCRMA.[4]

CCRMA has gone on to develop significant relationships with a wide portfolio of companies concerned with music, audio, computers and defense. In 1993, they expanded their commercial activities by developing, in partnership with the OTL, the Sondius trademark for products incorporating certain high-quality sound synthesis features. CCRMA is today widely recognized as one of the top computer music research centers in the world (Stanford Department of Music, 1979; Shurkin, 1983; Jungleib, 1987; Chadabe, 2000).

[4]Invention disclosure data for CCRMA is unavailable. But, the OTL estimates that approximately one-third of all Stanford disclosures are ultimately patented. This suggests that the patent numbers should be tripled to provide a rough indication of invention disclosures from CCRMA.

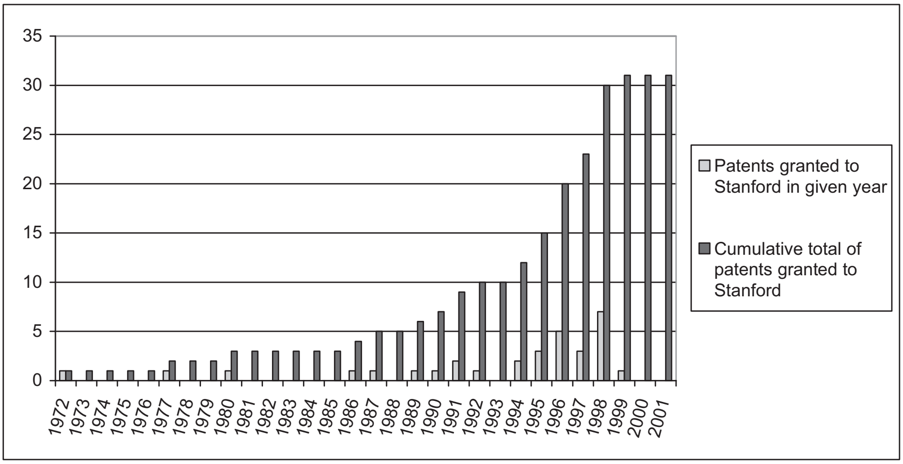

Figure 1 Patents Issued to Stanford University by Year of Granting for CCRMA-Developed Inventions

4. Key events and the initial institutional landscape

Individual agency played a major role in the history of the music department and the computer music group. This is particularly evident in the many key events in the account, including:

- Chowning's decision to attend Stanford University.
- Chowning reading Max Mathews' article.
- Mathews' responding with the Music IV program.
- Poole and Chowning playing in the symphony together.
- Chowning's FM synthesis breakthrough.
- Neils Reimers' interest and efforts in shopping the technology.
- The first NSF and NEA grants.
- Ishimura visiting Los Angeles and subsequently championing FM synthesis within Yamaha.

Path dependence (David, 1986; Arthur, 1989) provides a framework for understanding how such early key events may exert a significant and lasting impact on the outcome of historic processes. Chowning and Poole playing in the symphony together is an illustrative example of such a key event. Had Chowning and Poole not met due to their mutual participation in the symphony, Chowning would have faced considerable difficulty in attempting to run Mathews' Music IV program. Moreover, without Poole to mediate relations between the electronic music group and their hosts in the Artificial Intelligence laboratory, the former may have been denied access to the laboratory's resources. Finally, had Chowning and Poole never met, the Poole relationship could not have been called upon to supply CCRMA's first dedicated computer. Indeed, as Chowning recalled in reference to Poole, 'He was my angel' (Chowning, 1983).

Moreover, the full importance of these events—the fact that they would be coupled with the adjective 'key'—was not necessarily knowable except in a *post-hoc* account. In choosing to join the symphony, Chowning had no way of knowing that he would sit next to Poole and that the resulting relationship would be important to developing FM synthesis and ultimately to the success of Stanford's electronic music program. Even when these actions were intentional and deliberative, rather than idiosyncratic, no one could anticipate their full effect at the time. This, too, mirrors the emphasis within path dependence on the unpredictable effects of these early events (Arthur, 1989; David, 1986).

These early events took place, however, within a particular institutional context that shaped their effect. Three features of this institutional context are particularly salient: the open identity of the music department, the 'chair system' that served to isolate graduate students from institutional pressures to study 'the right thing', and Stanford's emphasis on interdisciplinary collaboration. I address each feature in turn.

When John Chowning entered Stanford, the music department was only 16 years old. While it drew inspiration from other university counterparts, it had not developed an internal identity as a department that had an emphasis in one particular area of music, such as composition or performance. In fact, the department saw the opportunity in being young to experiment with several novel programs. In addition to computer music, these included early dance (part of the department's unusual early music program, which is no longer active), performance practice and jazz studies. In all cases, program leadership was vested in individual faculty members.

Stanford's 'chair system' also ensured that students could pursue a thesis topic with a degree of isolation from departmental interests. Under the chair system, if a student's advisor supports a particular research topic, then the student is free to pursue it independent of departmental pressures. This decentralization serves to buffer students from coercion to study 'the right thing' and permits the exploration of unconventional topics—as long as the advisor is supportive. Leland Smith, Chowning's advisor, permitted Chowning to pursue a thesis topic about which Smith knew nothing. Moreover, as a graduate student with little to lose, Chowning was well poised to take advantage of this flexibility through the pursuit of offbeat research. As Chowning recalled, 'Not many universities would have allowed me the freedom to do what I have done' (Stanford Department of Music, 1982).

Finally, Stanford placed, and continues to place, a strong emphasis on interdisciplinary collaboration. In the decade of the 1960s, Stanford established seven formal degree-granting interdisciplinary programs, in addition to non-degree-granting centers. Indeed, Stanford's Artificial Intelligence Laboratory provides a good example of the latter. Officially established in 1962, just one year prior to Chowning's arrival, the lab drew researchers from a variety of disciplines (Buchanan, 1983). As Chowning recalled, these researchers 'intermingled and conversed as they waited for jobs to run

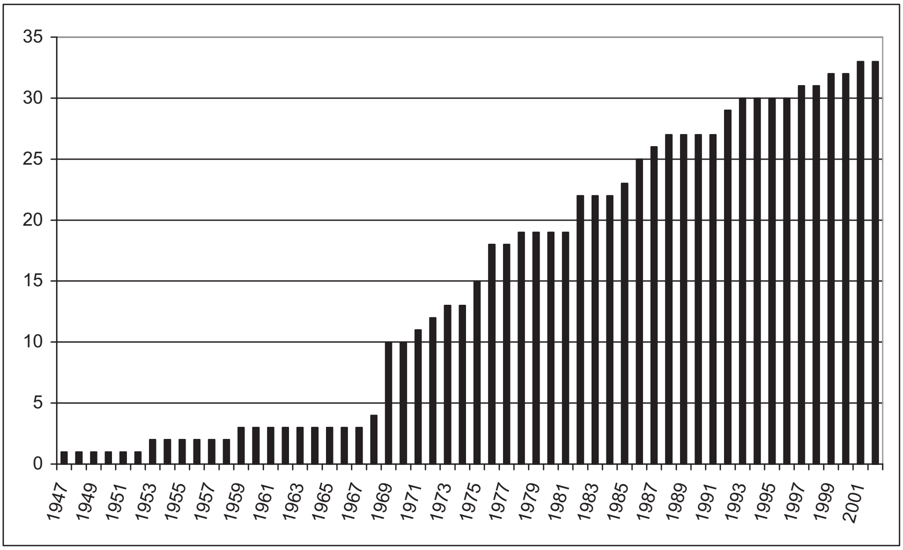

Figure 2 Number of Degree-Granting Interdisciplinary Programs at Stanford University, by year

or terminals to become free. Quite by chance, surprising and serendipitous alliances were made. Seemingly disparate fields found substantive connections' (Chowning, 1993: 3). The early collaboration between a musician (Chowning) and a computer scientist (Poole) was therefore not unusual in this environment.

5. A musical logic: the computer as an instrument

While an open identity, the chair system and interdisciplinary programs facilitated novel activity in the music department, the department still subscribed to an institutional logic based on music. That is, the department's emphasis was on the performance, history and composition of music. Chowning acknowledged this musical logic by framing the computer in a very particular way. Inspired by Mathews' 1963 *Science* article, 'The Computer as a Musical Instrument', Chowning positioned his work with computer sound synthesis not as an interesting project in and of itself. Rather, he argued that it would ultimately serve composers' needs by providing, in the words of his 1974 NEA/NSF grant application, 'a new medium of musical expression'. This was not technology for the sake of technology; it was essential that the computer be viewed as a musical instrument and that experimentation with sound synthesis would facilitate and advance musical composition.

The refrain of composition received frequent amplification from CCRMA. In 1975, Chowning argued, 'Our fundamental concern is with the development of musical compositions. There are many compositions which cannot be realized without the substantial contributions of scientific discoveries in the fields of computer science and electronic acoustics' (Klein, 1975). Subsequent newspaper accounts of the Center stressed that, 'the fundamental concern of the project is the development of new musical compositions' (Stanford Department of Music, 1976) and 'all research is tied to specific needs of compositions and composers' (Weiss, 1980).

6. The rise of a technical and commercial logic

While framed in terms of composition, however, the introduction of technology was accompanied by scientific and commercial interests whose ultimate concern was not music. This emphasis is immediately apparent in the first NSF grant awarded in 1975—the first ever awarded to a music department. In their application, Chowning and Smith were careful to stress the logic of scientific advancement, emphasizing their many technical breakthroughs. In reference to later NSF grants, Chowning asserted, 'these grants have been based on the scientific aspects of our work in psycho-acoustics and signal-processing' (Bailie, 1982). Similarly, the Yamaha license represented collaboration with a group that was not interested in producing new compositions, but rather in marketing electronic products to consumers for profit.

An emphasis on technology, rather than composition, is also apparent in early licensing activities. In 1968, for example, Chowning disclosed a 'Method and Apparatus for Simulating Location and Movement of Sound'. This method was subsequently patented by Stanford and licensed to GRT Corporation. In the years following, but prior to the Yamaha license in 1975, others involved with computer music at Stanford also disclosed inventions to Stanford.

This nascent activity must be understood in the context of Stanford's OTL at the time. From its inception, Stanford recognized the potential for 'practical applications' of university research. As Chris Chafe, CCRMA's current director, notes,

> one of the unique things about the charter of the university is that it would be this kind of a match between theoretical and applied knowledge… both were to be treated with the same sort of vigor. It's a distinguishing trait, if you look at parallel schools where it's much harder to pull off some of this synergy. (Chafe, 2002)

Stanford's relationship with industry grew dramatically in the years following World War II. While the war attracted large numbers of people to war-related industries in the San Francisco Bay Area region that is home to Stanford, the government awarded the majority of wartime contracts to East Coast firms. When Frederick Terman, who had nurtured his students William Hewlett and David Packard to success with Hewlett–Packard, assumed the position of dean of Stanford's School of Engineering in 1946, he immediately sought to strengthen both the university and locally based technology firms through increased collaboration. Terman also drew on important academic and government contacts, many of which had developed while he served as director of Harvard's Radio Research Laboratory during the war, to secure federal contracts both for the university and local firms. Nevertheless, Stanford's geographic separation left it at a disadvantage compared to its eastern counterparts, a fact that prompted Terman to focus his energies on building university–industry collaboration (Saxenian, 1994).

Still, technology licensing at Stanford was not commonplace in the 1960s. Since the early 1950s, Stanford had arranged with an outside firm, Research Corporation, to handle disclosed inventions (Mowery and Sampat, 2001a). Up to 1970, this arrangement had resulted in a total return to Stanford of less than $5000. In 1968, Neils Reimers joined Stanford as Associate Director of the Sponsored Projects Office, which negotiated contracts with research sponsors including the US government. Reimers believed that Stanford could develop an alternative, and superior, arrangement for transferring technologies to industry. He proposed a pilot program in the summer of 1968 that, uniquely, would be characterized by: a concentration on the marketing of inventions, licensing associates with individual authority to manage cases, the outsourcing of patenting to outside law firms, and the provision of incentives to inventors. With his own half-time commitment and one assistant, Reimers' program produced $55 000 in income its first year. The Office of Technology Licensing was established officially on 1 January 1970 (Wiesendanger, 2000). Thus, Chowning's 1968 'location and movement of sound' disclosure was one of the very first cases handled by Stanford (under Reimers) rather than Research Corporation. The license produced $5000 in 1969, accounting for nearly 10% of that year's total. In a sense, then, the computer music program and the OTL grew up together, disclosures from the former helping the latter to prove itself.

7. Technology and music in consort

The success of the marriage between music and technology seemed clear. By 1975, the computer music project had received significant grants from the NSF and NEA, had signed an important license with Yamaha, and had been officially organized as CCRMA. These and later successes in turn fed back into the music department through funding, increased prestige and the provision of new resources for composition. In turn, such feedback secured the place of the new technical and commercial logic in the music department.

In the late-1960s and 1970s, the music department was a small department with limited funds and a desire for growth (Smith, 1980). CCRMA not only did not compete with the department as a whole for resources during this development period, but also demonstrated through the initial NSF and NEA grants, along with the Yamaha license, that it could be a self-funded vehicle for departmental growth. Indeed, CCRMA proved so adept at attracting support that the School of Humanities

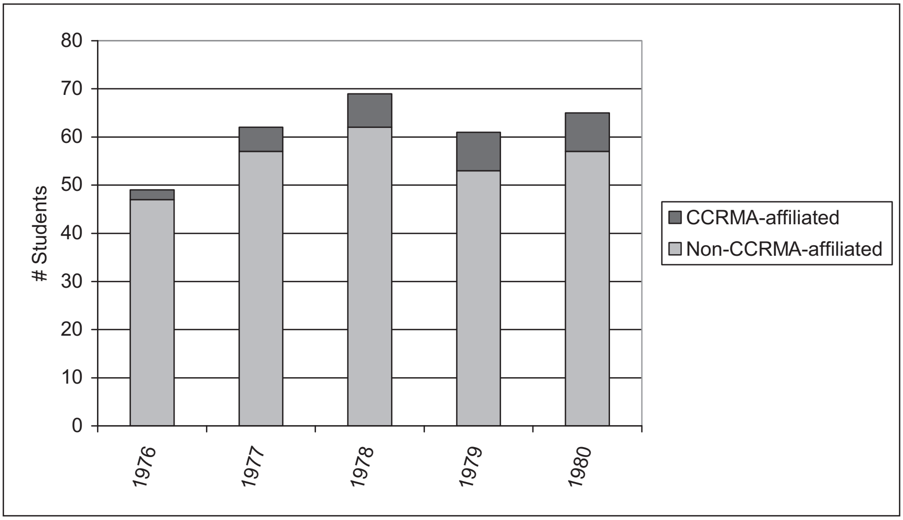

Figure 3 Number of Graduate Music Students with and without a CCRMA Affiliation, 1976–1980 (Computed by using a four-year moving window based on graduation statistics)

and Sciences as a whole took significant interest in its fiscal capabilities. This interest prompted the School to agree to donate its portion of the royalties on FM synthesis back to CCRMA to be placed in an endowment.[5] In an environment characterized by large dollar infusions into engineering, administrators realized that music, of all things, could make money, too.

CCRMA's success also enhanced the prestige of the music department. As early as 1967, Chowning's work on computer music brought national attention to the music department from *Newsweek* and CBS television. Following Chowning's success with FM synthesis and the awarding of the NSF and NEA grants, CCRMA was proclaimed as a premier center for computer music (Rogers, 1976; Stanford University Department of Music, 1979; Bailie, 1982; Lerner, 1983; Shurkin, 1983; Jungleib, 1987).[6] In a department perceived to lack a national reputation in other areas, CCRMA was an important element in recruiting top students in composition (*Stanford Daily*, 1982). In turn, these students furthered CCRMA's success.

Finally, CCRMA's success added to the music department by providing resources that shaped composition efforts. Figure 3 indicates the number of doctoral music graduates that were affiliated with CCRMA in these early years. The emerging role of

[5]Stanford's Office of Technology Licensing typically keeps 10% of license revenues for administrative costs. The remaining funds are split into thirds, with one portion going to the inventor, one portion going to the inventor's department, and one portion going to the School housing the department.

[6]While many media accounts supporting this claim were Stanford based and clearly held some bias, trade magazines and research journals upheld the view of CCRMA's eminence.

CCRMA in the music department as a whole is clear, and both reflected and encouraged an increased emphasis on areas of music that best made use of CCRMA's resources—primarily composition.

8. Amplification and introduction of institutional features

The harmonious relationship between music and technology encouraged the amplification of those institutional features that facilitated CCRMA's initial success, and the introduction of new features that reflected an emergent logic of technological development. In terms of amplification, CCRMA's success reinforced both flexibility in the choice of research subjects and interdisciplinary collaboration. Although the department is now 57 years old, it continues to maintain a broad repertoire of courses and faculty, which sustains openness to programmatic novelty. The chair system that protects novel research on the part of graduate students also remains intact. Moreover, the interdisciplinary collaboration that characterized Chowning and Poole's work together has been further institutionalized. By CCRMA's founding in 1975, about half of those working at the center were outside of the music department, representing diverse disciplines including engineering, psychology, medicine and computer science. As Chowning later remarked in a 1982 interview, 'It's difficult to imagine an environment so effectively interdisciplinary' (Stanford Department of Music, 1982). Figure 4 presents the historical composition of music versus non-music Ph.D. students affiliated with the program. The consistent mixture of disciplines is clear.

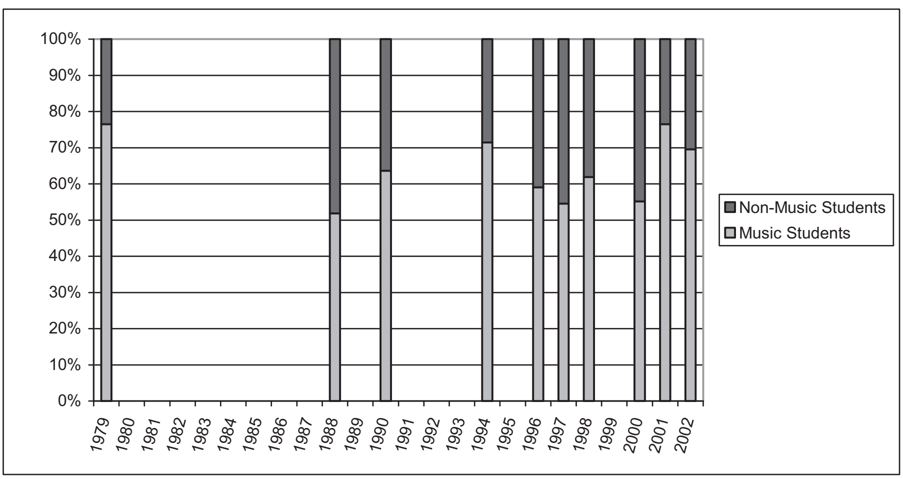

Figure 4 CCRMA-Affiliated Doctoral Students: Music versus Non-Music, percentage by year*
*Data are not available for missing years.

This interdisciplinary environment is facilitated by the size of both CCRMA and the university. As Chowning has argued, 'There's a critical size [for CCRMA]. If one gets beyond that, one loses contact with the people and the work that's being done' (Shurkin, 1983). Similarly, the university as a whole is, in Chowning's words, 'small enough for departmental boundaries to be violated' (Stanford Department of Music, 1982). Thus, an inverse-U shape curve may characterize size on one hand and fruitfulness of collaboration on the other: both CCRMA and the university need to be large enough to provide a broad and diverse set of 'raw materials'. At the same time, however, they cannot be *too* large, such that group members lose track of each others' research or such that a university department can function independently with little incentive to collaborate across disciplinary boundaries. Blau has argued that increased organizational size promotes structural differentiation, but that this inter-unit heterogeneity also implies a narrow span of control for managers (Blau, 1970). As units grown, individuals within them are less likely to be aware of outside happenings. Thus, Chowning's 'critical size' gains theoretical support.

Finally, CCRMA-director Chafe identifies an important positive feedback process related to interdisciplinary projects: individual departments favor interdisciplinary programs such as CCRMA because they help to attract faculty and they provide a

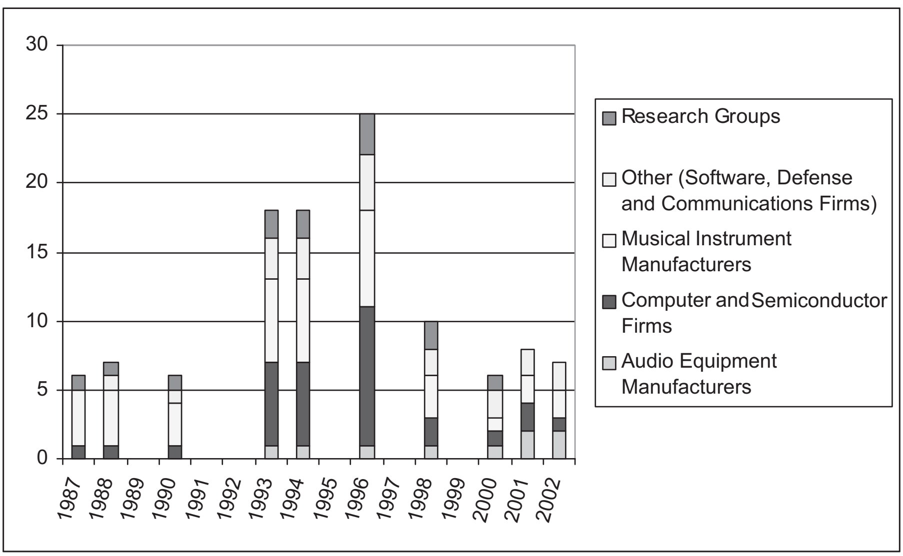

Figure 5 CCRMA industrial affiliates by year and categorized by firm type.*
*Data are not available for missing years. Per financial data from the university, the reduction following 1996 appears to follow from the introduction of stricter rules that only list firms paying in a given year and do not continue to list those firms that had paid in years past but not in the current year. Thus, the figures from 1993, 1994 and 1996 appear to be inflated by as much fifty percent.

forum through which disparate disciplines can come together to create new knowledge that transcends departmental boundaries (*Stanford Magazine*, 2001). In turn, the strength of these individual departments and the collaborative activities between them has fueled CCRMA's continued success (Chafe, 2002). Indeed, the quality of each department is crucial to such efforts. As Chowning argued in reference to CCRMA's early years, 'Stanford's strong Electrical Engineering and Computer Science departments, along with its strong commitment to the humanities, was the key to our getting along' (Stanford Department of Music, 1982).

8.1 New institutional features

The successful relationship between music and technology also led to new institutional features that reflect an emergent commercial and technical logic. These include an emphasis on patenting, the development of close relationships with industry, and the formation of a trademark program to adorn high-quality sound products.

While patenting had nothing to do with the genesis of computer music at Stanford, it has now assumed a central role in the music department and the university as a whole. This is reflected not only in CCRMA's continuing licensing and patenting activities (see Figure 1), but also in the growth of the OTL. In 1970, the Office consisted of one person (Neils Reimers) with three licenses and annual revenues of $55 000. The OTL Annual Report for FY03 reports 354 invention disclosures, 127 new license agreements and gross royalties of $45.4 m., with 24 employees. Part of this growth may be attributed to the Bayh–Dole Act of 1980, which specified that rights to inventions resulting from government-sponsored research activities would be automatically allocated to universities; previously, universities were forced to go through a lengthy petition process that varied between agencies to secure such rights. The intent of Bayh–Dole was to encourage collaboration between commercial concerns and non-profits such as universities, and even NSF funding came to reflect this priority. Stanford, of course, was active in licensing before Bayh–Dole. Indeed, given CCRMA's endeavors prior to 1980, it is difficult to argue that this legislation was responsible for their inventive or licensing activity. But, Bayh–Dole has amplified an existing stream of activity. Moreover, a 1980 NSF grant for CCRMA researchers to work with scientists from Systems Control Technology in Palo Alto under the Industry–University Joint Research Program reflects the increased emphasis on commercial collaboration (Stanford Department of Music, 1982).

This example highlights that change is apparent not only through increased patenting, but also through a general thickening of ties between the music department and industry. The Yamaha license both formalized industrial relations and introduced a financial incentive to accompany them. Given the uncertain state of FM synthesis technology, and the importance of its success to both the finances of CCRMA and the proving of the OTL, CCRMA had a vested interest in ensuring the success of this partnership. Thus, Chowning embarked on a series of frequent visits to work with Yamaha's engineers.

CCRMA maintains relationships with a wide portfolio of companies interested in a variety of technologies. As Chafe notes:

> There's a lot of work going on in other types of synthesis and other music related computer technologies and we have a real spread of companies interested in that. So, Yamaha is one and it's representative of the group of instrument manufacturers that are savvy about software and technology. But, it really spreads the gamut. We have instruments and controllers going on, automatic recognition going on, a lot of signal processing, all the Internet related stuff. It's a world that's expanded out ever since the early relationship [with Yamaha]. (Chafe, 2002)

In 1987, the Center formally established its industry affiliates program. Affiliates include primarily musical instrument, computer and semiconductor manufacturers, though research groups and audio equipment, defense, communications and software firms are also represented. Member companies currently pay $5000–30 000/year in exchange for the opportunity to attend conferences that expose them to the latest CCRMA research (CCRMA, 2002). This money is used to support CCRMA graduate students.

Chafe characterizes knowledge transfer via the affiliates program as 'more in the public domain fashion', meaning that companies can acquire research information through informal presentations and reports that involve no further contractual arrangements. Alternatively, information transfer can go through the OTL, which can encourage it through different stages of intellectual property protection and licensing. CCRMA projects fall on various locations along this continuum. As Chafe notes, 'We've got all variety right now . . . Some are totally open and some are totally OTL and everything in between' (Chafe, 2002).

At least as important as these formal arrangements through the industrial affiliates program and licensing, however, are the informal relationships that CCRMA maintains with a similar, and overlapping, portfolio of companies. These relationships are facilitated by the fact that CCRMA graduates founded and/or serve in many of these companies. By maintaining ties to Stanford, alumni and friends ensure that research discussions transcend university–industry boundaries. With the growth of the electronic music industry—particularly fueled by computer soundcards—the size of the network has increased significantly while Stanford has maintained its centrality.

Finally, CCRMA has engaged in trademark development. OTL's interest in trademark licensing was spawned by the enormous success behind the Dolby trademark. In 1993, OTL and CCRMA committed $425 000 each to develop the Sondius trademark, which includes a portfolio of Stanford music related projects that represent the best in audio technology. Thus, through a trademark CCRMA has enacted yet another approach to addressing commercial concerns.[7]

8.2 Institutional logics and multivocality

Earlier I argued that Chowning framed the computer as a musical instrument in order to match it to the institutional logic of musical composition. Such framing of foreign elements in terms of existing institutions can be a technique for institutional change (Friedland and Alford, 1991). Padgett has termed the use of one social or biological organizational form for a completely different purpose as *refunctionality* (Padgett, 2001). Others extend this from organizational form to institutions in general. Expanding on Bourdieu, Sewell, for example, discusses the 'transposability of schemas' in that 'the schemas to which actors have access can be applied across a wide range of circumstances' (Sewell, 1992: 17). Empirical evidence supports the contention that the use of existing institutional elements in novel ways may be accompanied by institutional change. Hirsch (1986), for example, has examined how the hostile takeover diffused in association with a change in the legitimating logic surrounding the concept. Similarly, Schneiberg (2003) argues that certain players in the US electrical utility industry were able to employ institutional elements from other arenas to successfully further organizational heterogeneity.

Historically, music composition at Stanford was an area that both affirmed and challenged existing music department norms. In remembering his early years as a graduate student, Chowning recalled that there was no 'party line' for the music department's composition program and that his fellow students pushed in many directions. He recalled the case of one 'far out' student who composed both a double-fugue for solo contrabassoon and an opera called *Buddha* and subtitled *Dry Dung*, which the music department refused to accommodate in the usual performance venue of Stanford's church (Chowning, 1983). In short, Chowning was not alone in employing a logic of composition while simultaneously challenging notions of what constituted legitimate 'composition'—and what activities might accompany it; the refunctionality and transposability of the logic of musical composition is clear.

The resultant technical and commercial logic is evident in the considerable licencing activity from CCRMA and its close ties with industry. Nevertheless, the emphasis on musical composition has not been supplanted. Rather, CCRMA personnel continue to emphasize a fundamental concern with composition. Indeed, when questioned about CCRMA's emphasis, Chafe replied, 'everyone has in common a musical foundation . . . [composition] is the glue' (Chafe, 2002).

At the heart of account, therefore, is the question of how a new technical and commercial logic interacts with musical composition. At times, they appear *not* to interact

[7] Interestingly, the trademark program has met with limited success. This is due not to a failure to enact technical expertise or to apply it to music, but rather to an attempt to address marketing and product development—two spheres in which they had no previous experience or engagement.

as different external parties seem to recognize only those specific features that are of interest: to some musicians, CCRMA is a composition center; to the NSF, it is a scientific research center; to the OTL and industry affiliates, it is a source of commercial research and development. But, as the case illustrates, the Center's success in each of these endeavors is critically dependent on its success in the others. In the early years of the Center, positive feedbacks between technical and musical foci encouraged the amplification and introduction of various institutional features. These feedbacks continue today. Specifically, the role of CCRMA technologies in funding both the music department and the university retains significance. Recognizing the role of technology licensing in funding compositional work at CCRMA, a 1992 memo from Chowning to Stanford Dean of Research Robert Byer claims: 'Our future is dependent on our ability to produce income.' Scientific and technological pursuits also generate ongoing grants for the Center. Finally, the university looked to CCRMA as a potential source to make up lost revenue from the cessation of the highly lucrative Cohen–Boyer rDNA license.

The interaction between technical and musical logics continues to be evident in the music department's prestige too. CCRMA retains its position as an élite center for computer music research (Chadabe, 2000). These efforts have enhanced the music department's ability to recruit top students in composition while elevating the status of the department as a whole (Jungleib, 1987). The growing centrality of CCRMA to the music department is apparent in the large percentage of music doctoral students who take advantage of the Center's resources. As Figure 6 indicates, the vast majority of

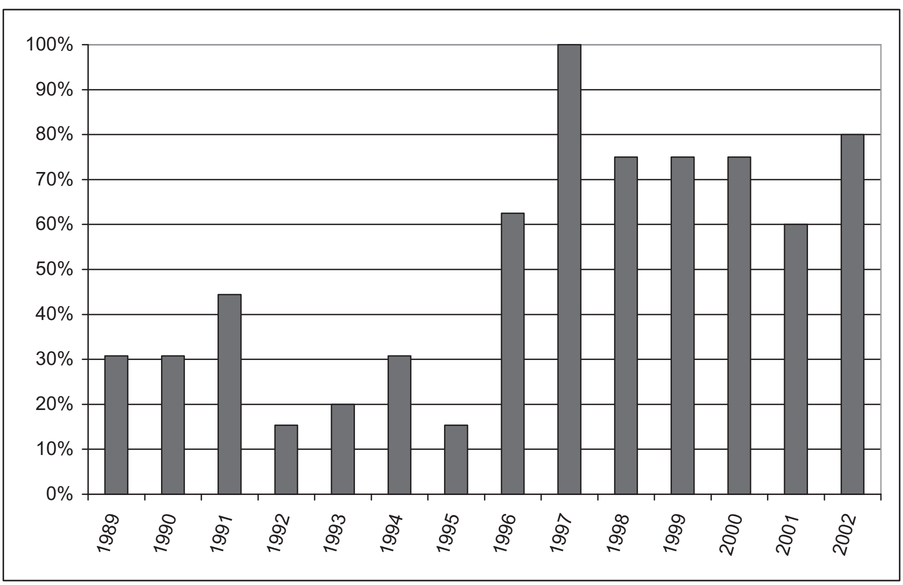

Figure 6 Percentage of Music Students Graduating with Doctoral Degrees Each Year That Have A CCRMA Affiliation, 1989–2002

music doctoral students are now affiliated with CCRMA, indicating that the technical and musical logics are blending, to at least some extent, in most students' experiences.

These positive feedbacks, which encourage a 'hybrid' logic, are not without challenges, however. Indeed, those involved with the Center describe a careful 'balancing act' that must take place between the various forces. CCRMA is strategically located in the music department to maintain this balance. While technical concerns can readily exploit the spillovers from musical endeavors, it is difficult to reverse the tables—to emphasize a dominant logic centered on technology—and hope for musical spillovers. As Chafe argues:

> This is a cross-disciplinary, very artistic, technical, everybody-helping-each-other kind of environment.... Imagine the facility being located in a more technical department what the barrier would be for musicians approaching. Would they feel that they're free to come join the project if it were headed towards engineering? (Chafe, 2002)

Thus, it is not only the multivocal environment, but also the strategic management of this environment through recognition of the competing logics it embraces, that is central to CCRMA's success. Ultimately, as Chafe explains CCRMA's disinterest in pursuing commercial interests at the perceived expense of musical emphasis and autonomy, 'The culture isn't built for that here' (Chafe, 2002).

9. Conclusion

The Stanford music department's licensing activities represent one of the most unusual cases of technology development at a university known for its embrace of university–industry interchanges. CCRMA's growth stemmed from ambitious individuals in a supportive institutional environment—individuals who understood how to employ an accepted logic in order to introduce novelty. The success of this endeavor led to both the amplification of particular institutional features and the introduction of new institutional features that reflected a new logic of commercially minded technologies.

In the Stanford case, the success of multivocality is critically dependent upon the maintenance of these dual logics rather than the submission of composition to commercial forces—a presumption recognized by those involved with the Center. This point is particularly important in light of concerns that increases in university patenting and licensing may be accompanied by an increased emphasis on applied research and a crumbling of academic autonomy (Rai and Eisenberg, 2002; Bok, 2003; Nelson, 2004). It is inescapable that several features related to CCRMA's musical roots help to maintain the emphasis on composition. These features include the fact that most current researchers have musical training, the fact that many of these researchers have created compositions using tools developed at CCRMA, and the fact that CCRMA was founded as part of the music department and the department retains administrative authority over the group.

To the extent that historical circumstance has aided CCRMA in balancing these multiple logics to result in truly positive 'positive feedback', an important lesson for future research would be to consider not only the multiple logics competing in university technology licensing, but also the historic evolution of those logics in the particular context in which they play out. For example, a group with a much stronger musical heritage than the Stanford of the 1960s might resist similar commercialization attempts; it would lack the open identity that allowed the FM synthesis experience to reverberate throughout the Stanford music department's institutional composition. Alternatively, music technology activities that began in an engineering school might have difficulty engaging the humanities side of music; they would lack the emphasis on composition that has facilitated a successful interaction of logics. In short then, research on multivocality must consider ways in which multiple logics might both positively and negatively interact and, critically, how historic circumstances may shape such interaction. Indeed, in other contexts, the outcome might not be a positive one.

Finally, the CCRMA experience highlights the importance of recognizing the individual-level embodiment of multiple logics. It is at the level of the John Chownings—the participants who in actuality both subscribe to and manipulate institutional rules—that the processes of institutional change and resilience may be found. And it is through these individuals that university technology licencing will proceed in whatever fashion it does.

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Address for correspondence

Andrew J. Nelson, Department of Management Science & Engineering, Terman Engineering Center, Stanford University, Stanford, CA 94305, USA. Email: andrew.nelson@stanford.edu.

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