Codification, patents and the geography of knowledge transfer in the electronic musical instrument industry

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Recent research in economic geography has emphasized tacit knowledge as the basis of industrial learning. In contrast, codification and the practices of industrial writing have received little attention for the roles they play in mobilizing knowledge across space. This paper offers insight into the geographies of codification through an examination of technology transfer in the electronic musical instrument industry between 1965 and 1995. The research draws on a variety of primary and secondary data that include interviews with inventors, biographical accounts and patent analysis. These sources offer perspective on the career trajectories of three U.S. inventors who transferred knowledge from various contexts in California's high-tech industry to the Japanese firm, Yamaha. Conceptually, the paper draws on the actor–network theory and Latour's idea of translation to highlight the detours inventors must take to register novelty. The analysis reveals the problematic nature of codified knowledge and its transfer; in this case codified knowledge was mobile internationally but not locally, at least until it reached Japan. The paper argues for the need to understand how texts such as patents are produced—the context of their authorship, the geographies of their circulation and their efficacy for shaping further innovative practice.

Les recherches actuelles en géographie mettent l'accent sur les connaissances tacites comme fondement de l'apprentissage industriel. Cependant, la codification et les pratiques relatives à la composition industrielle ont été peu étudiées du point de vue de leurs rôles dans la mobilisation des connaissances dans l'espace. Cet article donne un aperçu des géographies de la codification suite à une analyse du transfert technologique dans l'industrie des instruments de musique électronique entre 1965 et 1995. Fondée sur un ensemble de données primaires et secondaires, cette étude présente une série d'entrevues réalisées auprès d'inventeurs, des comptes-rendus biographiques et des analyses de brevets. Ces données permettent de considérer avec recul le cheminement professionnel de trois inventeurs américains responsables du transfert des connaissances depuis différents secteurs de l'industrie de haute technologie californienne vers la société japonaise Yamaha. Sur un plan conceptuel, l'article reprend la théorie acteur-réseau et aborde la notion de traduction développée par Latour afin de mettre en relief les principaux détours qu'empruntent les inventeurs pour obtenir un brevet d'innovation. L'analyse fait ressortir le caractère problématique des connaissances codifiées et de leur transfert;

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dans ce cas, les connaissances codifiées étaient mobiles à l'échelle internationale et non à l'échelle locale avant qu'elles n'arrivent au Japon. Cet article plaide en faveur de la nécessité de comprendre comment les textes tels que les brevets sont élaborés: le contexte entourant la rédaction du document, les géographies de leur diffusion et les répercutions sur les pratiques novatrices.

Introduction

Economic geographers have long recognized industrial learning as a situated process that is territorially and socially embedded. The vast literature on industrial districts, clusters and learning regions that accumulated through the 1990s emphasized place-based learning (Markusen 1996; Braczyk *et al*. 1998; Malmberg and Maskell 2002). More recently, a second current of inquiry has sought to unravel how learning takes place across space and between regions (Bunnel and Coe 2001; Oinas and Malecki 2002; Bathelt *et al*. 2004). Both groups of studies have frequently rehearsed Michael Polanyi's (1967) conceptual distinction between tacit and codified knowledge. In a world where codified knowledge is thought to be increasingly ubiquitous (Maskell and Malmberg 1999) many of these accounts view the leading edge, the quality that makes places special, as the province of tacit knowledge. In contrast there remains a lacuna in our understanding of how industrial geographies shape and are shaped by the practice of codification. This imbalance is regrettable, especially considering Nonaka and Takeuchi's (1995) widely cited observation that the cycling *between* codified and tacit knowledge holds the key to industrial problem solving. To address this research gap, it is necessary to more fully consider the codified dimension and the art of industrial writing.

Codified knowledge serves as the recipe for industrial learning. Codification is the process of inscribing information, the translation from practice to page or what Nonaka and Takeuchi refer to as 'externalization'. Maskell and Malmberg (1999, 15) capture the significance of this process when they state that 'technological progress is to a large extent the result of an interlinked process of knowledge creation and subsequent codification. Codification is thus at the heart of the whole philosophy of industrialization'. In the industrial arena, knowledge externalization produces several outcomes including blueprints, formulas, sketches and patents. Though each of these inscriptions fixes knowledge in a potentially mobile form, they vary according to the situated conditions governing their authorship and use. A patent serves as a more authoritative claim to novelty than an idea hastily sketched on a cocktail napkin.

Intellectual properties (IP)[1] are the currency of a knowledge-driven economy. Taplin (2004, 1) estimates that these sorts of intangible assets comprise 70 percent of the assets of major corporations. As Macdonald (2004, 135) argues, patents have acquired 'a strategic value increasingly independent of innovation'. IBM's patent portfolio, for example, annually generates U.S. $1 billion in profit through licensing. To produce a comparable figure, IBM would have to sell an additional $20 billion in products (Rivette and Kline 2000, 56). IP management has thus become a crucial firm competency to be integrated throughout the product cycle. According to its former vice president of R&D, when razor manufacturer Gillette sought to develop the Sensor brand, 'the first challenge . . . was *mapping* out the patent *landscape* surrounding the shaver's key performance attribute' (Rivette and Kline 2000, 58; emphasis added). Accompanying these spatial metaphors that hint at the tacit component of working with these inscriptions, is an increasing recognition that in the world of IP, geography matters. National patent systems across major industrialized countries differ significantly and firms face great uncertainty in both registering

1 Intellectual properties comprise patents, trademarks, copyrights and trade secrets.

and defending their patents across borders. The United States judges patents according to the 'first to invent' principle, whereas virtually every other country follows the 'first to file' system. However, moves towards international patent harmonization, such as the WTO's Trade Related Aspects of Intellectual Property (TRIPS) protocol, have been criticized by countries in the global south for undermining indigenous knowledge systems (Shiva 2000). As these examples illustrate, codified knowledge matters, yet there is a poor understanding of the processes through which patents and other industrial inscriptions are produced, mobilized and officiated.

This paper offers insight into the geographies of codification through an examination of the electronic musical instrument (hereafter EMI) industry between 1965 and 1995. This period is marked by two profound shifts in the EMI industry. First, the technological basis of the EMI industry shifted from analog to digital sound synthesis (Theberge 1997; Pinch and Trocco 2002). Second, the industrial advantage shifted decisively from the United States to Japan, specifically to Hamamatsu, an industrial city located on the Pacific coast midway between Tokyo and Osaka (Reiffenstein 2004, 2005). Yet, the key patents—a vital form of codified knowledge—that provided the catalyst for paradigmatic technological change were made by American engineers based in California, and American industry had the opportunity to access their breakthroughs. Why was this vital codified knowledge not properly appreciated in the United States? How and why was this codified knowledge transferred, understood, translated and elaborated by Japanese firms? These questions underline the problematic nature of codified knowledge in industrial location dynamics and regional development and provide the empirical goals of this paper.

Conceptually, I connect the themes of knowledge conduits with actor–network theory and Latour's science studies, especially in relation to the idea of 'translation'. Actor–network theory and Latour's idea of translation offer complementary insights into how knowledge networks are mobilized, including through the interdependencies between people (e.g., engineers) and things (e.g., patents). This discussion privileges patenting as a problematical process that connects scientific practice, engineers and innovation. Empirically, the paper sketches the career trajectories of three U.S. inventors who transferred knowledge from various contexts in California's high-tech industry to Yamaha, a Japanese firm based in Hamamatsu. In this transfer of knowledge, special attention is paid to the role of patents, most notably key 'breakthrough' patents that became the focus of considerable controversy. In terms of organization, the paper first elaborates on spatial transfers of knowledge through conduits and networks comprising people, texts and artifacts, primarily with reference to science studies and the theme of translation. Empirically, the paper then analyzes the role of engineers, firms and patents in the transformation and relocation of the EMI industry.

Knowledge Transfers, Codification and Translation over Space

The tacit–codified knowledge dichotomy is frequently the starting point for economic geography's examination of knowledge creation and transfer (Asheim 1999; Cowan *et al.* 2000; Johnson *et al.* 2002). Codified knowledge, also known as formal, explicit and articulated knowledge, concerns those forms of scientific or engineering knowledge that exist in textual form and are thereby potentially tradable. Tacit or informal knowledge, on the other hand, in Polanyi's (1967, 4) words is the highly personalized and contextual realm of knowledge in which, 'we know more than we can tell'. In practice the two are interdependent. As Nonaka and Takeuchi (1995; Nonaka *et al.* 2000) argue, knowledge creation proceeds from the cycling between tacit and codified knowledge. Geographers have seized on this mutually constitutive quality to caution against binary spatial logics that read tacit knowledge as local and sticky and codified knowledge as global and slippery. Asheim (1999) proposes an intermediate form of contextual knowledge, 'disembodied knowledge' that comprises locally sticky forms of codified knowledge. Bathelt *et al.* (2004, 31) similarly question 'the view that tacit knowledge transfer is confined to local milieus whereas codified knowledge may roam the globe almost frictionlessly'. While there has been increasing intimations about the importance of tacit knowledge in economic geography (Gertler 2004), the unpacking of codified knowledge has been left far behind.

Knowledge conduits

A useful, though limited, approach to understanding spatial knowledge transfer is to consider the conduits (texts, people or artifacts) through which it is exchanged. The so-called knowledge spillover literature focuses on the transfer of texts (Jaffe *et al.* 1993; Audretsch and Feldman 1996; Breschi and Lissoni 2001). These studies examine patent data, by looking for patterns of knowledge exchange. Howells (2002, 876) takes issue with the conceptual inferences derived from this type of data analysis, arguing that patent citations are a metric that, 'impl[ies] the imparting of knowledge, but do[es] not actually measure it'. Absent in the discussion of knowledge spillovers are discussions of how patents are produced—the context of their authorship, the geographies of their circulation and their efficacy for shaping further innovative practice.

For the second conduit, people, Pinch and Henry's (1999; Henry and Pinch, 2000) work on the British Motor Sport Industry (BMSI) cluster has tracked the movements of talent amongst enterprises. Their analysis highlights the turnover of engineers among competing teams. It further illustrates how knowledge was translated across sectoral boundaries to produce design innovations in the cars themselves—an element that recurred in the present study. Nevertheless, their emphasis on the exchange of tacit knowledge embodied in individuals hinders insight into the full spectrum of the knowledge cycle. A concept that might lend traction here is the notion of 'knowledge enablers', that is, agents usually operating within corporations, who facilitate the diffusion of tacit knowledge (von Krogh *et al.* 2000, cited in Gertler 2004). The challenge for these individuals, as Gertler (2004, 146–147) notes, is that it is 'devilishly difficult to disseminate' this knowledge without 'at least partial codification in the process of transmission'. In other words, the movements of people and texts need to be viewed as being complementary to each other.

Finally, technology transfer occurs through the mobilization of artifacts, such as consumer or capital goods. Especially in the case of complex machinery, Gertler has repeatedly (1995, 2001) called into question the limits to the transfer of these technological artifacts, a point commonly made about technology transfer by development scholars. On the other hand, reverse engineering, a central plank in the strategy of Japanese post-war reindustrialization (Freeman 1987; Partner 1999; Takahashi 2000), illustrates how artifacts, in concert with texts and expert advice, mobilize knowledge between places. This example affirms both the inadequacy of theorizations that treat people and things as operating in mutually exclusive domains and the need to look beyond North America and Europe. These issues are addressed in the communities of practice literature and by actor–network theory.

Communities of practice and actor–networks

Communities of practice are intra- and inter-organizational problem-solving networks (Wenger 1998). Debate in geography questions whether these communities effectively mobilize knowledge between locations. Amin and Cohendet (1999) assert that the organizational and relational closeness that define communities of practice substitute and even supersede physically proximate relations. Gertler (2001), however, expresses skepticism with the fact whether social or institutional proximities can really overcome distance. Coe and Bunnel (2003, 446) stake out an intermediate position in reasoning that, 'while such communities will originally almost certainly be local configurations, over time sustained and repeated interaction facilitated by "boundary crossers" may create new spatially extensive constellations'. Boundary crossers sound a lot like the knowledge enablers discussed earlier, suggesting, in part, that we are working through a conceptually cluttered space. In its emphasis of shared repertoires and stories of community participants, this literature is still primarily working through the idea of knowledge in the tacit dimension. This emphasis stands in contrast to actor–network theory.

Actor–network theory and the 'science studies' literature of Bruno Latour (1987, 1999) develop a conceptual framework and vocabulary to interpret the circulation of scientists and engineers through society. Actor–networks are so called since their architecture derives from the ability of humans and non-humans (machines, books, etc.) to enroll new actors into the network. Importantly, this perspective solves many of the difficulties inherent in the compartmentalized knowledge conduits approach since it views texts, people and artifacts as mutually constituting entities. It further opens up new possibilities for refining our understanding of the geographies of tacit and codified knowledge. Central to this perspective is the idea of 'translation', or the notion that within networks, actors are forced to 'take detours through the goals of others' (Latour 1999, 89). These 'translations' are the displacements in meaning and objective that result from the inevitable compromise among disparate interests. Within geography, various authors have illustrated the utility of actor–network and science studies' perspectives (Murdoch 1994; deLaet 2000; Barnes 2001; Winder 2001; Evenden 2004). Actor–network theory and translation also have particular reference to the practice of patenting and the detours that engineers are forced to take to authorize their inventions.

Patents and the inscription of actor–networks

In contrast to approaches that interpret patents as a proxy for innovation (Pred 1966; Schmookler 1966; Mensch 1979; Freeman *et al.* 1982; Ceh 2001), actor–network theorists begin from the assumption that patents are problematic. Their concern is with patents as texts, and the practice of patenting as a situated social process. Patents are instruments that actors use to 'mobilize the world' (Latour 1987, 223) in order to translate the interests of inventors and their assigning firms into the public realm. At sophisticated levels of strategic practice, patenting as a form of codification aims to snooker the competition by making it difficult for other parties to close the circuit between codified and tacit domains (Grandstrand 1999). Patents map new vistas of technological space at the same time as they enact a property claim that says, in effect: *do not enter*. Before reaching this plateau, however, patents must be carefully drafted through successive rewritings and demonstrations of originality before various audiences (peers, investors, examiners)—in other words, through a cycling between tacit and codified domains of knowledge. Myers (1995, 101) provides an excellent illustration of this process as he traces the procedures through which two scientists translate their journal articles into patent documents. In doing so they must negotiate the boundaries between 'the academic world of making knowledge and the legal world of owning things'. Patents further operate within a spatial topology distinguishable from other inscriptions. On the one hand, as deLaet (2000) suggests, patents conform to what Latour (1987) terms 'immutable mobiles', or a particular type of instrument that maintains its form in various contexts. This quality enables firms to act from afar, albeit indirectly through the legal system, to discourage infringement. On the other hand, this conceptualization is problematic, because the property rights associated with patents are less mobile than the inscriptions themselves. Consequently within and among various contexts, the 'tenacity' of patents may have as much to do with the intrinsic quality and originality of the technical claims as it does with the strength of the network that upholds these claims (deLaet 2000). Japanese industry, particularly since the 1970s has demonstrated an almost singular capacity for underwriting its economic and technological development with a sophisticated national approach to the mobilization of IP (Odigiri and Goto 1993).

Several studies have argued that the Japanese approach to patenting is predicated on a logic whereby the rewards for invention are measured in terms of social rather than individual benefits (Rosen and Usui 1994; Takenaka 1994; Kotler and Hamilton 1995; Granstrand 1999). The system within Japan has been designed to allow rival firms access to each other's patents soon after application with the purpose of improving the overall level of technological learning. In concert with a national innovation system (Freeman 1987) that encouraged technology imports, licensed or otherwise (Prestowitz 1989; Partner 1999), the value placed on knowledge codification at home gave Japanese industry a boost in international competition. At present five of the top ten firms awarded patents by the U.S. Patent and Trademark Office are Japanese (McKenna 2006). Granstrand (1999) discusses the strategies that produce such outcomes. The first involves gaining access to competitors' technological breakthroughs by 'surrounding' them with one's own patents, thereby engaging the competitor to seek cross-licensing agreements. The second strategy is to obscure an enterprise's own technological priorities by 'blanketing' the technological space around key patents with minor derivative and ancillary patents (Granstrand 1999, 220). Through the recognition of these practices it is possible to make sense of Japan's high patent propensity in various fields including EMIs. However, to solely credit the role corporate strategy plays in Japan's post-war industrial ascendancy, overlooks the few but significant episodes through which key ideas produced elsewhere were translated into the IP portfolios of Japanese firms. Indeed, by working backwards from the patents awarded to any firm, Japanese or otherwise, it is possible to produce a rather different narrative in which the credit for proprietary knowledge is less stable and more dependent on a broader network of actors than the assigning or licensing corporation.

Research Design

Methodologically, understanding how patenting and other processes of codification unfold in space requires tracing the actor–networks of inventors, firms, the patents they register and artifacts that follow. Those who work with patents are immersed in the tacit practicalities of writing and rewriting novelty. Yet, these actions produce a signature that enables comparison of the record of invention, the patent document, with other biographical and less objective accounts. With patent databases available in digital form, the record of codification is relatively straightforward to obtain. To evaluate the geography of patent registration, as a proxy measure for regional innovative output, I conducted an 'all field search' on the U.S. Patent and Trademark Office's Database (www.uspto.gov) using the term 'electronic musical instrument'. The data set consisted of all U.S. patents ($n = 2{,}375$) published between 1965 and 1995. Patents published after 1975 electronically list all the patents that reference that document. For those patents published before 1975, I had to undertake the time-consuming process of working backwards from existing patents to see which patents were cited as prior art. These tallies were used to construct lists of influential, widely cited patents. It was this process that produced the inventors and firms who appeared to exert the greatest influence on the technological trajectory of the industry. At this stage the methodological approach switched to that of biography.

Various authors have sought to problematize the role of biography in economic geography (Barnes 2001; Schoenberger 2001). Biographies, as Barnes (2001, 415) notes, 'are a mélange of fact and fiction—of events that happened, but also of rhetorical strategies, vested interests, and acts of interpretation, selective memory, and wishful thinking'. They connect career trajectories with corporate or other institutional interests and contextualize the harmony and dissonance that arise between the two. Cases of patent infringement bring into relief the uneasy tension between people, texts and artifacts noted by Howells (2002). Barnes (2001) offers further advice in sifting through the multiple worlds that constitute peoples lives. The biographer must first negotiate between the individual and their context (agency/structure). Moreover, there needs to be recognition that biography is the re-invention of lives in a manner that Livingston (1999; quoted in Barnes 2001, 415) calls 'controlled fiction'. Third, the position and intention of the author must also be clear. Barnes' analysis of the actor–networks that produced geography's quantitative revolution is instructive because it situates the production of texts in the context of the lives of their authors. This paper similarly embeds the inscriptions of inventors within their broader career biographies in order to illustrate what factors served to unmoor their contributions from their place of origin. The author is a student of industry who translated a practical interest in musical instruments into his doctoral thesis in geography. This article details a portion of that research project.

Codification and the Transfer of EMI Technology from the United States to Japan

Japanese firms headquartered in the city of Hamamatsu dominate the global musical instrument industry. In terms of sales, Yamaha, Kawai and Roland[2] sit one, two, and three atop the league tables (The Music Trades 2000). It is rare

2 Roland is nominally headquartered in Osaka, although the firm's principal administrative units and factories are in Hamamatsu.

to find examples, perhaps with the exception of Detroit during high-Fordism, where an industry's power is so spatially concentrated in one place. In the field of synthesizers and other EMI this locus of dominance extends to the Tokyo-based manufacturer Korg, which since 1988 has been 51 percent owned by Yamaha. It is curious that in the burgeoning list of English language accounts detailing technological evolution in the EMI industry (Chadabe 1997; Theberge 1997; Pinch and Trocco 2002), there is scant mention of the agency of Japanese firms. Instead, the emphasis is on the role of key centres like Bell Labs and Stanford University, institutions such as the Audio Engineering Society (Reiffenstein 2005) and inventors such as Bob Moog who rank as the pioneers of the analog era. Indeed, after diffuse early developments in places like Russia and Germany, America had emerged by the 1950s as the crucible of electronic music, a position it held through the 1970s and then promptly lost to the Japanese. Apart from elegies to the demise of the once great U.S. EMI industry (Milano 1993) there is a critical gap in our understanding of how the technological transition from analog to digital sound is linked to the geographical shift in the industry's center of gravity from the United States to Japan.

The Japanese literature, on the other hand, offers several perspectives on the industry's evolution in that country. These include stories told by the firms themselves as corporate histories (Yamaha 1987; Kawai 1997; Roland 1999), autobiographies of firm founders (Kakehashi 2002), books written by leading engineers (Mochida and Aoki 1994) and other interpretive accounts (Nakagawa 1984), including research reports published by geographers (Ohtsuka 1980; Takeo 1988). Notwithstanding these contributions, with the exception of Johnstone (1994, 1999), there is a dearth of research that explains the role that technology transfer from the United States played in the ascendancy of Hamamatsu's musical instrument industry, and it is this lacuna which this paper addresses. The investigation begins with an assessment of the patent record.

The lessons and limits of patent data

From the early 1970s, Japanese firms, especially those located in Hamamatsu, had eclipsed their American counterparts in the registration of U.S. patents (Table 1). Indeed by the 1990s, the former industrial core of the Midwest, home to such formerly venerable instrument manufacturers as Wurlitzer, Hammond,[3] Lowery and Kimball, had ceased to be a factor. In contrast, these descriptive statistics confirm that Japanese instrument manufacturers placed an increasing strategic premium on the registration of intellectual properties with the U.S. Patent and Trademark Office. What they do not indicate, and herein lies the limitations of patent counts, is the range of practices that lies behind the figures. They tell us little about how corporate and individual inventor biographies converge in the patent domain—how texts are rendered and how these texts beget other texts, producing what Latour (1987) terms 'chains of translations'. The following empirical material is presented to show the relative roles of codification and tacit knowledge in the transfer of innovative power from California to Hamamatsu, Japan. This will be accomplished through case studies of three key EMI inventor/engineers in the 1970s and 1980s.

Career Biographies and the Process of Codification

The remainder of the paper presents the career biographies of three Californian engineers whose inscriptions enabled the translation of knowledge to the Japanese firm Yamaha. The engineers are Ralph Deutsch, Dave Smith and John Chowning. These engineers connect the demise of the United States as an industrial core to the ascendancy of Japanese firms. Indeed in all three cases, potential U.S. allies balked at the opportunity to enroll the engineers in a domestic network. That these individuals and their milieu failed to connect is especially surprising since the inventors were working in institutional settings—the Southern California aerospace industry (Deutsch), Silicon Valley (Smith) and Stanford University (Chowning)—that are normally associated with

3 Interestingly, the Wurlitzer and Hammond names live on as digital sound 'patches' on synthesizers. My Korg synthesizer offers, respectively, 'Amp Driven Wurly' and 'Rotor Organ' files that evoke the analog tones of these vintage instruments. The Hammond Organ brand was acquired by Hamamatsu-based Hammond-Suzuki in 1988.

Table 1
U.S. patents for electronic musical instruments by region of assigning company 1965–1994

	Europe	U.S. East	U.S. Midwest	U.S. West	Japan Kanto	Japan Hamamatsu	Japan Kansai	South Korea	Total
1965–69	18	46	138	24	4	9	3	0	242
1970–74	11	62	149	40	13	177	12	0	464
1975–79	9	34	91	20	9	150	23	0	336
1980–84	23	47	110	17	38	239	18	0	492
1985–89	15	19	12	16	73	177	8	0	320
1990–94	2	10	3	23	109	353	14	7	521
Total	78	218	503	140	246	1,105	78	7	2,375

SOURCE: USPTO (http://www.uspto.gov); last accessed 21 April 2006.
U.S. East are those states bordering the Atlantic, U.S. West include the Pacific States and Arizona, while the U.S. Midwest are all the rest, but primarily Illinois, Ohio and Indiana. Japan Kanto includes Tokyo, Saitama and Kanagawa prefectures, Japan Kansai includes Osaka, Kyoto and Hyogo prefectures, while Japan Hamamatsu records those patents registered in a concentrated area of western Shizuoka prefecture surrounding the city of Hamamatsu.

California's post-war ascendancy as a center of technoscience. In contrast, Yamaha proved eager to wed its interests with these U.S. engineers, to mobilize the latter's inventions by licensing, assigning or citing their inventions. Against these similarities, the three inventors differ in their approaches to codifying the knowledge they produced. Ralph Deutsch, according to his tally of published patents, was the most prolific inventor in the EMI field, John Chowning recorded one highly significant patent while Dave Smith never registered a single patent.

In constructing these narratives I relied on my own interviews with Ralph Deutsch and Dave Smith in addition to secondary sources that include firm histories (Yamaha 1987; Markowitz 1989), interviews and oral histories contained in trade publications (Vail 1993) and other interpretive accounts (Nakagawa 1984; Johnstone 1999).[4] These multiple biographical sources serve as a counterpoint to reflect on the public accomplishments of these individuals (patents, instrument designs, etc.) while illustrating the social (as opposed to technical) dimension of innovation.

4 Comprehensive accounts of Chowning's contribution to EMI and Yamaha are detailed in Johnstone (1994, 1999). Consequently, he was not interviewed.

Vignette I: Ralph Deutsch—knowledge mobilization through the reinscription of one's own idea

The outline of Ralph Deutsch's contribution to the evolution of EMI is as follows. Through the 1970s and 1980s Deutsch was one of the most prolific inventors in the field of EMI, registering more than 140 patents. During its lifetime, Deutsch's 'digital organ' patent (U.S. Patent 3515792), the first patented rendering of a musical tone in binary code, was cited more than 114 times in subsequent patents, more than any other similar document (Table 2). He authored four of the top ten most cited patents in the field. These accomplishments, however, have been overshadowed by a restless career the shifts of which have proven highly controversial. Several U.S. and Japanese firms, among them, North American Rockwell, Yamaha and Kawai have sponsored his inventions (Table 3).

The story that animates these facts is complicated by conflicting vantage points. Details that Deutsch narrated to me sit uneasily alongside the highly critical account of Deutsch found in the autobiography of Jerome Markowitz (1989), President of Allen Organ, the Pennsylvania firm that licensed the digital organ technology from Deutsch's employer, North American Rockwell. In reference to Deutsch, the dust jacket of Markowitz's (1989) *Triumphs and Trials of an*

Table 2
The top ten most cited U.S. patents for EMI, 1965–1994

Year	Cites	Assignee name	Assignee address	Assignee sector	Inventor address	Inventor name U.S. patent number
1970	114	North American Rockwell	Pasadena, CA	Aerospace	Sherman Oaks, CA	Deutsch, R. 3515792
1971	111	North American Rockwell	Pasadena, CA	Aerospace	Tustin, CA	Watson, G. 3610799
1974	91	Deutsch Research Labs	Sherman Oaks, CA	Musical Instruments	Sherman Oaks, CA	Deutsch, R. 3809786
1991	80	Stanford University	Stanford, CA	Education	Menlo Park, CA	Smith, J. 4984276
1993	66	Pioneer	Tokyo, JP	Electronics	Tokyo, JP	Okamura, M., *et al.* 5247126
1975	62	Yamaha	Hamamatsu, JP	Musical Instruments	Hamamatsu, JP	Tomisawa, N., *et al.* 3882751
1977	58	Stanford University	Stanford, CA	Education	Palo Alto, CA	Chowning, J. 4018121
1973	52	North American Rockwell	Pasadena, CA	Aerospace	Sherman Oaks, CA	Deutsch, R. 3763364
1972	50	North American Rockwell	Pasadena, CA	Aerospace	Sherman Oaks, CA	Deutsch, R. 3697661
1967	50	Seeburg	Chicago, IL	Jukebox	Gilford, NH	Campbell, R. 3358068
1983	49	Yamaha	Hamamatsu, JP	Musical Instruments	Hamamatsu, JP	Nagai and Okamoto 4383462

SOURCE: USPTO (www.uspto.gov); last accessed 21 April 2006.

Organ Builder highlights, 'How one of the key figures in the development of digital musical technology *sold out* to a leading Japanese company' (emphasis added). One of Markowitz's chapter titles is: 'Ralph Deutsch and the Dark Side'. Not surprisingly, Japanese authors (Nakagawa 1984) paint a different picture. In piecing together this legacy, the challenge is one of achieving balance between the hard facts and claims of Deutsch's prodigious patent record, Deutsch's actions and the multiple interpretations of those actions.

On 8 August 1967, Pasadena, CA-based North American Rockwell (hereafter Rockwell) and their engineer Deutsch filed a patent application for the digital organ. Soon after, Deutsch demonstrated this invention to the large U.S. organ manufacturers, almost all of whom failed to

Table 3
A synopsis of Ralph Deutsch's patenting record

Assigning firm	Dates	Number of patents	Number of patents with co-inventor	Legal representation (Patent agent/attorney)
N.A. Rockwell	1970–1974	9	1[a]	Haman & Humphries
Deutsch Research Labs	1974–1979	17	5[b]	1)Howard Silber (Flam & Flam); 2) Ralph Deutsch
Yamaha	1974–1977	20	3[c]	Howard Silber (Flam & Flam)
Kawai	1977–1989	94	23[b]	Ralph Deutsch
4 firms	19 years	140 patents	32 co-invented	3 different legal representatives

[a] George Watson, employee of Autonetics Division Rockwell.
[b] Leslie Deutsch, son of Ralph Deutsch.
[c] Glen Griffith, Tustin, CA.
SOURCE: USPTO (http://www.uspto.gov); last accessed 21 April 2006.

appreciate its significance, or balked at the potential development costs. Markowitz's firm Allen Organ proved to be the solitary interested party. Rockwell licensed the technology to Allen and Deutsch headed the team of engineers responsible for developing and delivering the digital circuit boards to Allen. Unfortunately, Rockwell an aerospace firm, and Allen an organ manufacturer, perceived the technological horizon forged through their partnership in fundamentally different ways. In drafting the contract Markowitz (1989, 77), 'expressed [Allen's] requirements in the technical language familiar to us and Deutsch 'translated' these requirements into the 'foreign' language of the new technology'. Markowitz (1989, 70) dubbed this language 'Anaheim tech-speak'.

This linguistic detour produced a compromise. Markowitz was impressed with the digital circuitry of the prototype but dissatisfied with its tonal expression. Beyond these technical concerns, personal differences between Deutsch and Markowitz almost scuttled the relationship. Nevertheless, in June 1971 Rockwell delivered the digital organ prototype to Allen and its technical attributes proved immediately apparent. For example, Allen's analog organs took one week to test whereas the circuitry of the digital organs could be tested in under an hour (Ralph Deutsch, personal communication, 12 October 2002, conversation). More importantly, Allen's license of first refusal to exploit the digital organ technology proved vital to the firm's long-run fortunes. Competitors who sought to enter the digital arena had little choice but to sign licenses with Allen or infringe on the patent. Largely due to the royalties derived from this patent, Allen survives as the only major organ company that is still American-owned.

At the North American Music Merchants (NAMM) trade convention in June 1971, Deutsch arranged a private demonstration of Allen's digital organ to Yamaha's president and an entourage of 25 delegates. In January 1972, Deutsch left Rockwell and a few months later was hired by Yamaha for a 3-year contract to produce technologies for their Electronic Organs (Electones). Deutsch headed the New Electone System (NES) division, one of two internal teams created at Yamaha to develop instruments for the digital age. While the NES initiative was geared towards a digital solution to the problem of tone synthesis, a parallel program operating out of the newly constructed Toyooka factory focused its efforts on an analog/digital hybrid system known as PAS (passive analog system). These two teams developed a healthy rivalry whereby

> Deutsch's appearance stimulated a competitive spirit at Toyooka's PAS development centre and also raised the aggregate power for developing the logic circuit which had thus far proved to be a major hurdle ... The PAS team had the spirit and determination that it was not acceptable to lose against Deutsch (Nakagawa 1984, 86–87; translation by the author).

After a year and a half of this bifurcated development, an internal trial was staged in front of Yamaha's President Kawakami Gen'ichi[5] who selected the PAS system. Deutsch (personal communication, 12 October 2002, conversation) summarized this setback by noting that Yamaha only partially incorporated the technologies he developed and patented on their behalf. He was also critical that his remuneration package did not include royalties accruing from any of his patents.

During the Yamaha contract, Kawai approached Deutsch to undertake a similar function with regard to that firm's digital organ program. This turn of events, not surprisingly, proved controversial, and Yamaha threatened to sue Deutsch for breach of contract. Deutsch defended himself by citing the non-exclusive nature of their contractual obligations. Moreover, as he claimed, 'there was nothing worthwhile [in our relationship] that was not covered by the patents' (Ralph Deutsch, personal communication, 12 October 2002, conversation). The knowledge Deutsch codified for Yamaha, in this sense, was absolutely crucial both in terms of his remuneration and in terms of the firm's ability to proprietize his contribution. However, to suggest that the patents could operate independent of Deutsch's tacit interpretation of their contents is indeed a stretch—it is the cycling between the two that ultimately mattered. Put another way, it is difficult to suggest any action by Deutsch that was not in some way tethered to the patents he authored. The following episodes illustrate this point.

5 Japanese names are rendered according to the convention whereby the family name precedes the given name.

How did codification facilitate Deutsch's break from the Rockwell–Allen partnership and the transfer of knowledge to Yamaha? Or, as the author of one of the most fundamental technologies in the field, could he separate his own tacit knowledge that formed the basis for the digital organ patent from the codified knowledge inscribed in that patent? In early 1972, after leaving Rockwell but before joining Yamaha, an independent Deutsch Research Labs applied for a 'Computor Organ' (sic) patent (U.S. Patent 3809786), the third most cited patent in the field (Table 2). This patent claimed to 'exhibit . . . all of the listed advantages of digital wave shape generation', a nod to his own Rockwell–Allen digital organ patent (U.S. Patent 3515792), 'yet in a manner totally different from that known in prior art'. The latter invention's tonal quality was 'determined by the stored harmonic coefficient values' as opposed to the 'actual storage of a digital representation of a waveshape'. Notably, it was preferable that 'the harmonic coefficients are stored in digital form and the computations are carried out digitally'. The extent to which U.S. Patent 3809786 had its basis in U.S. Patent 3515792 and in Deutsch's work for Rockwell–Allen is far from straightforward as evidenced by what followed.

Deutsch, R&D staff in the Electone division at Yamaha and eventually Deutsch and engineers in the R&D division at Kawai soon published a battery of ancillary and dependent patents that laid claim to a large portion of intellectual space and served to discourage rivals form entering the increasingly digital realm of EMI. Many of these documents referenced either the digital organ patent or its cousin the 'computor' organ. Complicating matters, Yamaha instruments that seemed dependent on these technologies started appearing in the marketplace. Allen's objections to these actions resulted in initial and retaliatory lawsuits not only between Allen and Yamaha, and Allen and Kawai, but also between Allen and other American organ makers who also appeared to be infringing. By Markowitz's (1989, 124) reckoning, the computer organ patent, and much of Deutsch's subsequent work for Yamaha, contravened the Allen–Rockwell contract. Eventually, Yamaha and other Japanese firms, in recognition of Allen's position, settled. These lawsuits underline the significance of the disputed knowledge and the inseparability of technological and inscriptive dimensions of industrial novelty.

The lawsuit between Indiana-based Kimball International, Inc. and the Allen Organ Company lasted between 1981 and 1988—the latter accusing the former of infringement[6] and the former contending the latter's patent was invalid.[7] Much of Kimball's claims of invalidity rested on the fact that Deutsch and Rockwell had 'demonstrated' its digital organ technology to Rodgers and Conn (two other U.S. manufacturers) more than a year before it filed for the digital organ patent. The act of demonstration, Kimball argued, implied that this knowledge was already extant, or in the terms of patent law in 'public use', a condition which if proven would invalidate the patent. Eventually, the jury granted Kimball a pyrrhic victory. Adrift in a sector where success was increasingly contingent upon owning intellectual properties for digital, as opposed to analog, technologies, Kimball like most other U.S. EMI manufacturers soon went out of business. Inscriptions such as key patents both tie together and work to modify the behaviour of various actors in innovation networks. Indeed, it is fair to describe this episode as illustrative of a community of practice in which the members, to use Wenger's (1998) phrasing, are 'passionate' about their vocation. In this case, though, the actions of the U.S. EMI manufacturers proved creatively destructive for one another.

The story continues, for U.S. Patent 3515792 (p. 22) met with critical reappraisal when an anonymous competitor petitioned the U.S. Patent and Trademark Office in 1985 to re-examine its claims. The result of this scrutiny was that in 1987, one year prior to the expiry of the patent, every one of its 46 claims were cancelled. Someone had signalled to the examiner a far more extensive body of prior art than was contained in the original patent document. When it was granted in 1970, Deutsch acknowledged five patents as prior art; upon re-examination, 104

6 Allen Organ Co. *v.* Kimball International Inc., Nos. 86-767, 86-789, UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT, 839 F.2d 1556; 1988 U.S. App. LEXIS 1763; 5 U.S.P.Q.2D (BNA) 1769, February 12, 1988, Decided.

7 Kimball International Inc. *v.* Allen Organ Co., No. EV 78-73-C, UNITED STATES DISTRICT COURT FOR THE SOUTHERN DISTRICT OF INDIANA, EVANSVILLE DIVISION, 1981 U.S. Dist. LEXIS 17329; 212 U.S.P.Q. (BNA) 584, May 1, 1981.

patents and 32 other documents were cited as prior art. Articles published in the *Journal of the Audio Engineering Society* (*AES*), technical reports published by Bell Labs and other documents were brought forward to suggest that Deutsch's digital step was not as radical as claimed. Deutsch admits in hindsight that there are conceptual similarities between his early work and that of Max Matthews of Bell Labs (Ralph Deutsch, personal communication, 12 October 2002, conversation). Nevertheless, for close to 15 years, the musical instrument industry operated under the assumption that the Rockwell–Allen patent defined the state of things to come. In this sense the patent's 'tenacity' (deLaet 2000) proved radical even if the technology amounted to the most officially (if incorrectly) sanctioned articulation of the state of the art at the dawn of the digital frontier. That such a significant patent was awarded with what in retrospect appears to be only a cursory examination is by no means a unique occurrence (Wall Street Journal 2006).

Deutsch's career path traces a geography through a number of key firms in both the United States and Japan. As framed by Markowitz, this migration was a matter of 'selling out'. From the Japanese standpoint, Deutsch served as a catalyst to an instrument development program that was far more sophisticated than any firm in the United States—witness Yamaha's decision to make its own microchips (Nakagawa 1984).[8] Deutsch's contribution goes far beyond these migrations. Patents bearing his name as the inventor (140 in total), and notably U.S. Patent 3515792, cast a long shadow over the trajectories of both his assigning firms and those companies forced to navigate the technological space demarcated by these documents. In particular, the tenacity of the digital organ patent shaped the actions of rival firms, and the actions of Deutsch when he went to work for those rivals. Moreover, his story captures the process that Nonaka and Takeuchi (1995) refer to as the 'cycling' between tacit and codified forms of knowledge. For instance, pertinent court cases turned on the scrutiny of codified knowledge (specifically the claims in the patents) relative to Deutsch's actions (demonstration). Deutsch's decision to become his own patent agent (Table 3), to advocate on behalf of his inscriptions reinforces the idea that there is a tacit dimension to the process of codification.

8 Yamaha had originally sought to buy generic chips from NEC and Hitachi, but these proved inadequate for their needs so the firm set about to produce application-specific chips. They dispatched their best and brightest engineers to train at the laboratory of the leading Japanese scientist in the field, Nishizawa Junichi of Tohoku University. Armed with this practical knowledge, the cohort returned in 1969 to oversee the set-up of Yamaha's Toyooka laboratory and factory outside Hamamatsu. By 1976 Yamaha was mass-producing chips at Toyooka and at a second factory in Kagoshima (Nakagawa 1984). By the 1990s, Yamaha's specialization paid off. In 1994, Yamaha's sound chips accounted for 95 percent of sales of the $1billion market for sound boards (Johnstone 1994). However, in 2003, Yamaha sold its integrated circuit division to the Kyoto-based Rohm Corporation.

Vignette II: John Chowning—knowledge cycling and the genesis of the Stanford–Yamaha license

The case of John Chowning and the FM synthesis patent is another story of spatial knowledge transfer that links a key patent authored by a Californian inventor with the Japanese firm Yamaha (Johnstone 1994, 1999). In the early 1960s, Chowning was a graduate student of music composition at Stanford University. Inspired by a paper published by Bell Labs' Max Mathews (1963) in the journal *Science,* Chowning shifted his course of study to computer music. He visited Bell Lab's in New Jersey, met his guru and returned to Stanford with Mathews' computer music program. He enrolled in computer science courses and spent 5 years at Stanford's Artificial Intelligence Laboratory connecting the theory of computer music to its practical application.

One night in late 1967 while tinkering with a pair of oscillators, using one to control the pitch of the other, he made an 'ear discovery'.

> At a frequency of around 20 Hz, he noticed that instead of an instantaneous change in pitch from one pure tone to another, a recognizable tone color, one that was rich in harmonics, emerged from the machine. It was a discovery that an engineer would have been unlikely to make. What Chowning had stumbled upon, it later turned out, was frequency modulation—the same technique that radio and television broadcasters use to transmit noise-free signals. Of this, the composer was blissfully ignorant: All he wanted to do was make colorful sounds. Chowning began tweaking his algorithm and pretty soon, as he recalls, 'using only two

oscillators, I was making bell tones and clarinet-like tones and bassoon-like tones, and I thought, you know, this is interesting' (Johnstone 1994, 3).

Chowning by this stage was a junior faculty member in the music department. Unfortunately, there were few colleagues capable of confirming the radical nature of his discovery.[9] Part of the problem is that Chowning had yet to 'connect his ear to the theory' (Johnstone 1999, 217). As Johnstone (1999) explains:

> This conjunction would not occur until 1971, when Chowning remembered some synthetic trumpet tones that a Bell Labs researcher had played for him and wondered whether he could indeed achieve a similar effect using FM synthesis. It turned out that he could indeed produce some quite realistic brass tones. It was at this point that Chowning realized that his technique was a lot more than he had first thought.

In order to realize the potential of his invention, it was necessary for Chowning to enlist others with a similar tacit knowledge base into the ensemble. When Chowning presented his discovery to the staff at Bell Labs, its significance was indeed apparent, especially to Max Mathews' boss John Pierce who instructed Chowning to 'patent it!' In other words, Pierce commanded Chowning to both protect his invention and complete the knowledge cycle from its tacit state back to a form that could be translated to others. Since Stanford was not in the business of manufacturing, this idea had to be pitched to those who could put Chowning's recipe to use.

With echoes of the cold shoulder given to Rockwell and Deutsch by all of the U.S. industry save Allen Organ, in 1971 Chowning encountered a similar inability of U.S. EMI manufacturers (including the firms Allen, Hammond and Lowery) to comprehend what was shown to them. Despite Chowning's entreaties, he failed to align his invention with the technical aspirations of any domestic firm. Hammond Organ of Chicago, for instance, responded to Stanford's invitation by sending four engineers and a professional organist. While the latter was impressed with what he heard, the engineers failed to recognize that this technology heralded the dawn of a new frontier. Here are Chowning's thoughts about that meeting:

> They kept asking me about how many pins it would need. Well, I didn't know anything about pins, chips or analog circuitry at all so I couldn't answer them. I said, 'Look, it's an algorithm and *here's the code* [but] it was simply not part of their world' (Johnstone 1999, 221; emphasis added).

This is a good illustration of what Asheim (1999) calls 'disembodied knowledge' for Chowning's algorithm was a text that proved opaque to those outside a community of practice with an insufficient stock of tacit knowledge. Yamaha, on the other hand, sent an engineer, Ishimura Kazukiyo, with a background in communications technology. Ishimura, in Chowning's words, 'took all of ten minutes' (Johnstone 1994), to grasp the technology and immediately initiated negotiations to take out an exclusive license on the patent. From the standpoint of Ishimura's boss, Mochida Yasunori, FM synthesis dovetailed perfectly with Yamaha's objectives.

> As an engineer, you are very lucky if you encounter a simple and elegant solution to a complex problem, FM was such a solution and it captured my imagination. The problems of implementing it were immense, but it was such a wonderful idea that I knew in my heart that it would eventually work (Johnstone 1994, 5).

If it was tacit knowledge that enabled Ishimura to grasp the import of Chowning's demonstration, Yamaha's costly appropriation of the technology had to be defendable through an exclusive license.

In 1983, 10 years after they started developing applications based on Chowning's invention, Yamaha released the DX7, the world's first, all digital programmable, polyphonic synthesizer. Pinch and Trocco (2002, 317) regard the DX7 as the 'breakthrough digital instrument, the first one to achieve commercial success'. Whereas the signature synthesizer of the early 1970s, the Minimoog, achieved lifetime sales of 12,000, the DX7 sold over 200,000 units in 3 years (Colbeck 1996).

For Stanford, Silicon Valley's nearest and most important institutional neighbor and a university

9 Phil Lesh, avant garde composer, and Grateful Dead bass player, was one contemporary who recognized and supported Chowning's achievement (Johnstone 1994).

Table 4
Technological relations binding Stanford University and Yamaha

Date of invention (of agreement)	Technology	Details of Stanford–Yamaha relationship
1968 (1975)	FM synthesis—invented by John Chowning	Yamaha takes out an *exclusive license* on the FM technology.
1985 (1989)	Waveguide synthesis sampling—invented by Julius O. Smith III	Waveguide synthesis is licensed in a *non-exclusive* fashion to Yamaha and California firms such as Chromatic Research, Crystal Semiconductor and Seer Systems
(1997)	Sondius-XG	*Joint licensing agreement* to cooperatively promote the development and use of their respective intellectual property portfolios (over 400 patents and applications) in the computer tone generation and sound synthesis areas. The Sondius program is Stanford's first effort to not only patent discoveries made on campus but to trademark them as well.

SOURCE: Johnstone (1999); http://www.sondiusxg.com/presrelease.html; last accessed 21 April 2006.

synonymous with academic–industry collaboration, Chowning's invention has become the second-highest generator of royalties for its Office of Technological Licensing (Johnstone 1999). Stanford's relationship with Yamaha has persisted to the mutual enhancement of both parties (Table 4). Most importantly, the royalties from Chowning's FM patent funded the establishment of Stanford's Center for Computer Research in Music and Acoustics (a.k.a. 'Karma'). CCRMA currently employs 14 research and teaching faculty including John Chowning and Max Mathews. Successive generations of key basic technologies that include Julius Orion Smith's wave guide sampling patent (Table 2, #4) have served to keep Stanford at the leading edge in forging university–industry liaisons. Primarily these relations have been channelled through Yamaha. Importantly, the relationship has recently evolved to a joint licensing arrangement that weds the basic research of Stanford with Yamaha's applications. For the relationship to work, though, a tacit arrangement is not sufficient, the partnership must be codified.

Vignette III: Dave Smith and the perils of not patenting

Dave Smith is the inventor of the Prophet 5 synthesizer, the world's first mass market programmable instrument. He is also recognized for the leadership role he played in launching MIDI (Musical Instrument Digital Interface), the protocol that would enable the everyday connection of computers and musical instruments (Chadabe 1997). Smith entered the world of electronic music armed with a degree from UC Berkeley in computer engineering and work experience in Silicon Valley's aerospace and computer industries. Smith further had a background as an amateur bass player in San Francisco's music scene. Of interest to this paper is that in the patenting arena, Smith does not register. It is this difference in the way that he approached the problem of codification, especially as it concerns the transfer of knowledge to Japanese firms that I seek to highlight.

In 1977, as President of Sequential Circuits, Dave Smith licensed a polyphonic keyboard patent from a firm based near Santa Cruz, CA called E-Mu. Since his fledging firm had consumed most of its financial resources in getting the Prophet-5 keyboard to market an agreement was made to postpone royalty payments. By 1979 the success of Prophet-5, the world's first instrument to incorporate a microprocessor, had vaulted Sequential to the head of the industry and the royalty checks which Sequential could now afford to write to E-Mu represented a large transfer of funds. This cash flow in turn helped finance the R&D efforts of E-Mu. However, in May 1980, the staff at E-Mu received a letter from Smith informing them that he had decided to stop paying royalties on the Prophet-5 design. A lawsuit between the two ensued. According to E-Mu's founder Dave Rossum, 'E-Mu went from having a positive cash flow to having a fairly substantial negative cash-flow to pay the lawyers to get Sequential to pay us the money that we thought they owed us' (quoted in Vail 1993, 199). The two parties eventually settled out of court in an amicable fashion.

Over the course of the Sequential–E-Mu relationship, the latter's patent worked in a number of ways. At the outset, the patent sanctioned the transfer of codified knowledge in a manner that was only partially consistent with the conventions of licensing. Such a soft agreement between the two firms was likely the outcome of a shared entrepreneurial culture: one that was perhaps even embedded in a larger set of loosely defined regional codes of practice that characterized the formative days of Silicon Valley (Saxenian 1994). A little later, after the patent's worth had proven itself, Sequential, for a time, recognized this value by conceding royalties to E-Mu. The termination of royalty payments is more difficult to interpret except to say that Sequential viewed the worth of the E-Mu patent in limited terms. Finally, the lawsuit and resolution prove the immense power of this inscription to discipline the behaviour of the disputing parties. Nonetheless, this experience shaped Smith's views on the value of patents thereafter.

> We never patented anything at Sequential. It was partially the cost, partially laziness and partially my own philosophy which was that in most cases if you are trying to patent something then it is only as good as your ability to defend it.... If you have a lot of patents then you are pretty well covered and nobody is going to come after you (Dave Smith, personal communication, 11 October 2002, conversation).

In contrast, with no patents to bolster their position, Sequential Circuits, had little to fall back upon when sales slumped in the mid-1980s and the firm became a takeover target for Japanese competitors. These firms were already familiar with Smith, since he was the lone American keyboard manufacturer with the prescience to collaborate on the non-proprietary MIDI protocol. Though he had discussed the idea of initiating a common serial interface with several U.S. firms, the detour proved too daunting.

> No one in the States seemed to be interested...and we lost interest trying to round everyone up, so we worked with the Japanese companies (quoted in Chadabe 1997, 195).

In 1988, Sequential was bought by Yamaha, closed 6 months later and reopened by Tokyo-based Korg, who that same year had become 51 percent owned by Yamaha. Without a patent portfolio, what role did other forms of industrial writing play in the transfer of knowledge from Sequential to Yamaha-Korg?

> One of the things I did when I [first] came over to [Yamaha] was I brought a two-page list of products that could be built—brief descriptions, a paragraph on each one. Some of them were follow-ups of products that we had already done and others were new ideas. I was describing one of our ideas for a new product and so I was drawing some stuff on the board...Basically, what I drew on their [Yamaha's] chalkboard was the original concept, describing this stuff, saying how it's going to work, it's going to have these things, etc. And the net result of the meeting was their engineers saying, 'Well we don't think that's going to work'. And I said, 'Well, sure it's going to work'...We ended up doing the product, not for Yamaha, but for Korg (Dave Smith, personal communication, 11 October 2002, conversation).

Yamaha's engineers had not been working through the same sort of ideas as Smith and thus could not initially appreciate his inscriptions. But once presented with this recipe, they were in a position to act. Interestingly, their first act appears to be one of re-inscription. A few years later, it was to Smith's surprise that the following episode transpired.

> I was looking through a trade magazine—the *AES Journal* always prints a summary of patents in the back, a paragraph on each one—and I was browsing through it just to see what was going on. I was reading one from Yamaha, because, of course, they always have a bunch of them in there. And I thought, 'wait a minute', that sounds familiar. So I went back and re-read it and it was basically a patent of what we were doing for that synthesizer and it was based on those drawings that I did when I was describing it to them (Dave Smith, personal communication, 11 October 2002, conversation).

That these ideas first echoed to Smith while he browsed the *AES Journal* also points out that inscriptions, even scribbles, once translated into patent form, perform in a variety of contexts.

Table 5
A selection of U.S. engineers employed by Japanese EMI manufacturers

Name	Employment prior to Japan	Employment for Japanese firms
Ralph Deutsch[a]	North American Rockwell 1965–1973	Contract invention and consulting for Yamaha 1973–1975, Kawai 1975–1986
John Chowning[b]	Stanford University Department of Music 1966–present	Licensed FM synthesis patent to Yamaha, consulting 1975
Dave Smith[c]	Founder and President of Sequential Circuits 1974–1988	Headed Yamaha DSD 1988–1989, Korg R&D US 1989–1994
John Bowen[d]	Moog Music 1973–1976, Sequential Circuits 1982–1987	Yamaha DSD 1988-89, Korg R&D US 1989–1998
Chris Meyer[d]	Sequential Circuits 1984–1987, Digidesign 1988–1989, Marion Systems 1990	Roland R&D 1990–1997 (tasks included analysis of competitors intellectual property)
Roger Linn[e]	Founder and President of Linn Electronics 1978–1986	Contract invention for Akai 1987–1994
Tom Oberheim[f]	Founder and President Oberheim Electronics 1970–1985, Marion Systems 1987–present	Contract invention for Roland 1988–1990
Alberto Kniepkamp[g]	Head of R&D for Lowery Organs 1965–1969, Norlin 1969–1978	Patent and product design consulting for Roland 1989–present
Herb Deutsch[h]	Hofstra University and Moog Music 1964–1977, Norlin	Contract consulting for Roland
Carlo Lucarelli[g]	Technical manager Farfisa (Itl), Founder president of SIEL (Itl.)	President of Roland Europe 1988
Dennis Houlihan[g]	Lowery Organs, author of ‘Owner’s Manual’, VP Marketing	President of Roland US
Anthony Billias[d]	Professional Musician, Music Retail Shop Floor Demonstrator	Product Specialist at Korg, Director of Marketing for Technology Products Yamaha
John Lemkuhl[d]	Music retail	Synthesizer voicing Korg 1988
Nick Howes[d]	Degree in Astrophysics, Professional Musician, Music Retail (UK)	Yamaha R&D (UK) 1992–
Mark Moffat[i]	Studio Engineer EMI (Aus) 1972–1980, Record Producer, Nashville 1982	Contract consulting for Roland 1978–

SOURCES:
[a] Personal communication, 12 October 2002, conversation.
[b] Johnstone 1999.
[c] Personal communication, 11 October 2002, conversation.
[d] Sonik Matter website (http://sonikmatter.com), accessed 01 April 2004.
[e] Roger Linn Design website (http://www.rlinndesign.com), accessed 01 April 2004.
[f] Sound on Sound website (http://www.soundonsound.com/sos/1994_articles/mar94/tomoberheim.html?session=95455209cfc1c8b0c61ed0dd6b190e0a), accessed 01 April 2004.
[g] Kakehashi 2002, 149–151.
[h] Herb Deutsch website (http://www.hofstra.edu/academics/hclas/music/music_deutsch.cfm), accessed 01 April 2004.
[i] Roland User’s Group on-line newsletter (www.rolandsus.com/community/rug/Fall_01/currents.asp), accessed 02 December 2002.

In the case of the *AES Journal* they communicated to a particular community of practice both what Yamaha was doing and, in theory at least, what Yamaha could proscribe others from doing.

Smith’s story should be further highlighted because it sets the mould for a subsequent pattern of U.S. engineers who became vectors of knowledge transfer to Japan, once their firms failed (Table 5). Several of Smith’s team at Sequential Circuits found employment with various Japanese EMI manufacturers. Chris Meyer, for example, turned his tacit knowledge to IP analysis for Roland. The eponymous firms of Roger Linn and Tom Oberheim failed, as Sequential did. Thereafter, Linn did contract work for Akai, while Oberheim turned his talents to problem solving for Roland. Alberto Kniepkamp, once Lowery’s head of engineering who subsequently worked for Norlin before it too was dissolved, gained employment with Roland as, among other things, a patent consultant. Denis Houlihan, author of Lowery Organ’s ‘Owner’s Manual’, translated his knowledge and, importantly, technical writing skills to Roland. Indeed, Japanese EMI makers have selectively hired specialists from all facets of the production chain, from R&D to retail in their efforts to absorb knowledge from their former American competitors. In several of these cases, individuals were hired so that their tacit knowledge could be applied in some capacity to the analysis and codification of texts.

Codification in Practice and Theory

A comparison of the Deutsch, Chowning and Smith career trajectories is instructive for several reasons. To summarize the vignettes, Deutsch travelled to Japan to work with Yamaha; Chowning patented at Stanford but his landmark FM synthesis patent was licensed to Yamaha; and Smith gave tacit knowledge to Yamaha who later patented his idea. In their own way, each of these biographies illustrates that knowledge formation was the result of a cycling process between tacit and codified domains. The case studies affirm that tacit knowledge matters, but, not surprisingly in highly idiosyncratic ways. For example, rational calculation did not precipitate Chowning's 'Eureka!' moment, his 'ear discovery' of FM synthesis. As Johnstone (1999, 216) infers, it was a discovery that 'an engineer would have been unlikely to make'. Nevertheless, Chowning's musical training, his later interest in learning the practicalities of computer science and his connection to Bell Labs contributed to his stock of tacit knowledge. Yet what ultimately put this knowledge in play was the moment of externalization when Chowning and Stanford fixed this knowledge in a proprietary manner by patenting and licensing it to Yamaha.

In addition, a combination of institutional contexts and individual practices shaped the approaches to and outcomes of knowledge codification. For Ralph Deutsch it was prudent to patent every single technology he developed since it was this practice that would safeguard his interests as he moved among several corporations. It was his way of making sure that he and his inscriptions became indispensable within an evolving network of (often competing) interests. Crucially, the act of codification made his contributions translatable across space, but it was still necessary for him to travel to Japan to demonstrate to Yamaha (and subsequently Kawai) the practical application of his inventions. In the case of FM synthesis, Chowning's lone patent cemented a relationship between Stanford and Yamaha, the legacy of which is CCRMA, an institution that has fostered the development of a number of fundamental technologies that have directly benefited both the university and Yamaha. Finally, for Smith, the entrepreneur, the inscription of knowledge in patent form was a practice more suitable for those with the resources and energy to defend that knowledge. Smith's approach to codified knowledge, whether in respect to E-Mu's patent, or to the designs he jotted down on Yamaha's blackboard, appears far more relaxed and perhaps naive than Deutsch's. This might be a personal or generational matter; it also might indicate a difference in the industrial cultures of the Los Angeles aerospace industry versus that of the milieu that blossomed at the intersection of the Bay Area music scene and the Silicon Valley community.

The way that these individuals related to Yamaha is additionally instructive in what it says about the geographies of embedding, disembedding and reembedding of knowledge from one setting to another. At the outset, these engineers acted as 'boundary crossers' who cultivated a body of knowledge positioned at the cusp between two communities of practice: electronics and music. In the case of Deutsch and Smith this setting was the high-tech sector in California at a time when military technologies were being applied to meet consumer ends. For Chowning, the network he forged with Bell Labs and the training he undertook in Stanford's computer science department would appear to have provided a sufficient basis for further translations. However, in attempting to translate these quite radical sets of knowledge to the American EMI, each of these individuals faced resistance from prevailing habits of thought held by their geographically proximate peers: the digital organ idea was rejected by most U.S. firms; Chowning's FM idea was not part of Hammond's 'world'. Even Smith, who at the time was the bright young star of the U.S. synthesizer industry, could not persuade his U.S. colleagues of the importance of MIDI. It is also surprising, at least in the Chowning and Smith cases, that Silicon Valley, a region that stands as the bench mark for industrial learning, failed to adopt these radical ideas. Smith, for instance, was unable to secure venture capital from outside sources to finance Sequential. Indeed, the utter lack of local linkages stands out and calls into question Markowitz's claim that Deutsch 'sold out'. In fact, like Smith and Chowning, the only detour available to Deutsch entailed working with the Japanese.

In each case, Yamaha was prescient enough to offer these individuals the best deal to facilitate the translation of their interests. Even at this stage, the transfer of knowledge was far from straightforward and translations had to be performed in both the literal and figurative sense. Deutsch took it upon himself to learn Japanese. The only way for Smith to communicate was via a blackboard. In their relations with Yamaha, both Deutsch and Smith found that their ideas were not automatically celebrated or their roles privileged. Deutsch's NES lost out to the PAS in the Yamaha trials of 1974, while Smith left his meeting at Yamaha with the belief that they were not going to use his ideas—they were just scribbles, after all. In the final analysis, each of these contributions played a role in transferring knowledge to Yamaha. Deutsch acted as a pioneer in the implementation of digital sound, Chowning transferred the method by which digital synthesis could be realized, while Smith's collaboration on the MIDI protocol enabled the entire horizontal integration of the industry that swung in the Japanese favour in the latter half of the 1980s.

Conclusion

This case study sheds light on how the practice of industrial writing shapes industrial geographies. By emphasizing codification it lends balance to a dialogue that has perhaps overstated the importance of tacit knowledge. The history of industrialization is one of geographical concentration and dispersal (Hayter 1997). While it is too much of a simplification to say that the accumulation of tacit knowledge explains the concentrations and codification the dispersals, the ability to translate ideas to new contexts is greatly facilitated once knowledge has been inscribed. The problem, however, is that those inscriptions rarely operate independent of the network of inventors, firms and, importantly, other inscription in which they are embedded. This is why the practice of asserting novelty through writing and enacting property claims based on these writings, in short patenting, is so fraught with potential hazards. The problem is especially acute when new, radical knowledge is produced. In these cases the scripts that might lend context to these inventive leaps are absent and the ability to enroll other actors into the network hinges on whether they possess a common frame of tacit knowledge. This study demonstrated that proximity is not necessarily a good predictor of whether or not these connections between actors will be forged. When a connection is made and novelty recognized, the new linkage must be externalized. Contracts must be signed, key patents licensed and new derivative patents codified to anchor the translation. The motives and actions of individuals and firms may shift and strain against these anchors, with the result that whole projects may come unmoored and displaced. Through a juxtaposition of the roles of inventors and their writings in the spatial transfer of knowledge, I have sought to highlight the complexities that arise when Nonaka and Takeuchi's (1995) knowledge cycle is spatialized.

The paper makes the further methodological argument that economic geography has made effective, but ultimately partial use of patent statistics. It critically reflects on the knowledge spillovers school and its method of counting patent citations. Indeed, there appear to be several logics of citing 'prior art' not all of which are straightforward indicators of the significance of a given invention. Rather, particular inscriptive practices appear to wed important inventions with insignificant derivative patents, the latter serving as noise, to complicate the landscape for imitators. Patents are not merely an outcome of research, a proxy metric for innovation. These records are the tip of the iceberg—meaningless when divorced from the mass of individual tactics, corporate strategies and institutional settings that characterize the authorization of novelty. When closely examined, they present just one facet of the lives of inventions or the inventors who create them. In highlighting this juxtaposition, the study further proposes a biographically informed actor–network methodology that tracks the connections forged between people, inscriptions and artifacts.

This perspective additionally enabled empirical insight into the debate in geography over whether 'communities of practice' can be made to operate at a distance (Amin and Cohendet 1999; Gertler 2001; Coe and Bunnel 2003). In particular, this case study suggests that it is in the absence of community—inventors who could not conform to the practices of corporations and inter-firm alliances, engineers with genuinely novel ideas that could not win the support of their (local) peers, etc.—when actors are forced to mobilize their knowledge to new contexts. Moreover, by focusing attention on the practice of patenting, this paper provided illustration of how inscriptions work to include or exclude parties from a community. With this evidence in mind, the social architecture of communities of practice would appear more suited to function both locally and at a distance only when the problem to be solved is well defined. In contrast, during episodes when new technologies are in their infancy and the path forward is uncertain, the process of knowledge transfer across boundaries is complex and cannot easily be determined in advance.

Further research is required to understand the comparative institutional contexts that embed practices such as patenting; for instance, by examining the work of ancillary actors that include patent attorneys, examiners and contract reverse engineers. Historical analyses inform us of discreet national examples (Kumagai 1999; Lamoreaux and Sokoloff 2002), yet there have been few systematic studies that update the pioneering work of Penrose (1951) or, more critically, address the manner in which mobilized IP bring these systems into collision. Especially in an era of purported harmonization between the conventions of European, American and Japanese patent regimes, it is imperative to assess the degree to which each of these regional contexts serves to modify the traffic of intellectual properties that move across their frontiers. For example, Japanese patent law allows the submission of applications in English, under the provision that they be translated into Japanese prior to examination. What sort of technical or linguistic detours does such a process entail? How does geography matter to these processes of codification?

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