Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer

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As a key driver of innovation and economic growth, university-industry technology transfer has attracted significant attention. Commentators often characterize “formal” technology transfer, which encompasses patenting and licensing university inventions, as proceeding according to market principles. Within this dominant conception, patents disclose and “commodify” academic inventions, which universities then advertise and transfer to private firms in licensing markets.

This Article challenges and refines this market-oriented model of technology transfer. Drawing from empirical studies, it shows that formal technology transfer often involves long-term personal relationships rather than discrete market exchanges. In particular, this Article explores the significant role of tacit, uncodified

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knowledge in effectively exploiting patented academic inventions. Markets, patents, and licenses are ill-suited to transferring such tacit knowledge, leading licensees to seek direct relationships with academic inventors themselves.

Drawing on the theory of the firm, this Article then argues that these relationships often mature into deeper forms of organizational integration involving faculty inventors, universities, and licensee firms. Presenting a descriptive theory of university-industry technology transfer, it contends that the difficulties of conveying tacit knowledge encourage various forms of organizational integration by which licensees directly absorb faculty inventors (and their tacit knowledge) into their operations. From consulting arrangements to seats on boards of directors, licensees are bringing academic human capital in-house to facilitate commercialization of patented university inventions.

Turning from the descriptive to the normative, this Article assesses the opportunities and drawbacks of academic-industrial integration and offers proposals to improve technology transfer while safeguarding academic norms. It concludes by exploring the implications of tacit knowledge for patent theory and the organization of technology commercialization activities.
INTRODUCTION

In his 2012 State of the Union address, President Barack Obama argued for robust federal funding of scientific research, stating, “Innovation . . . demands basic research. Today, the discoveries taking place in our federally financed labs and universities could lead to new treatments that kill cancer cells but leave healthy ones untouched.” President Obama’s statement is noteworthy on several levels. First, it represents yet another manifestation of the federal government’s longstanding commitment to funding basic scientific research. From establishing land-grant colleges in the nineteenth century to funding the Human Genome Project, the federal government has provided and continues to provide enormous support for scientific inquiry. Second, it illustrates the close


connection between technological innovation and economic growth, as President Obama framed federal research funding as a key strategy for stimulating the economy amidst the “Great Recession.” Third and most relevant to this Article, President Obama’s statement reflects widely held presumptions about the nature of scientific and technological progress.

Tellingly, President Obama spoke of funding basic research, which is performed largely at universities and national laboratories, but he characterized the payoff of such research as commercial applications, such as cancer treatments. Universities and national laboratories, however, are not in the business of developing commercial technologies. That function falls to the private sector, and the link that connects publicly sponsored research and private-sector commercialization is technology transfer. This Article explores this link in detail.

In an indirect way, President Obama may have been talking about SynapSense. SynapSense is a “cleantech” start-up that enables wireless metering of data centers, thus reducing energy consumption by companies. Like many cleantech start-ups, SynapSense is a university “spinout.” Dr. Raju


5. See also Barack Obama, Remarks by the President in State of the Union Address (Jan. 25, 2011, 9:12 PM), available at http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address (“[B]ecause it’s not always profitable for companies to invest in basic research, throughout our history, our government has provided cutting-edge scientists and inventors with the support that they need. That’s what planted the seeds for the Internet. That’s what helped make possible things like computer chips and GPS.”). Thousands of products originated in university research, including Bufferin, computer-aided design (CAD), diagnostic tests for cancer and osteoporosis, Gatorade, Lycos, music synthesizers, stannous fluoride, Taxol (an anticancer drug), and the “gene splicing” technique that produced the biotechnology industry. See John Fraser, Communicating the Full Value of Academic Technology Transfer: Some Lessons Learned, 28 LICENSING J. 1, 2 (2008), reprinted in 1 TOMORROW’S TECH. TRANSFER 9, 10 (2009); Donald S. Siegel et al., Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies, 21 J. ENGINEERING TECH. MGMT. 115, 118 (2004) [hereinafter Siegel et al., Effective Transfer].


8. This Article focuses on university technology transfer, setting aside specific focus on national laboratories for a later date. However, many of the same dynamics concerning technical knowledge transfer also apply to national laboratories. Cf. Barry Bozeman, Technology Transfer and Public Policy: A Review of Research and Theory, 29 RES. POL’Y 627, 636 (2000) (exploring similarities and differences between universities and national laboratories in generating and transferring technology).

Pandey, a computer science professor at the University of California, Davis (UC Davis), originally developed SynapSense’s core technology. UC Davis applied for a patent on this technology and granted an exclusive license to SynapSense. While university spinouts are not uncommon, SynapSense illustrates an underappreciated facet of many of these arrangements. Dr. Pandey, who remains a member of the UC Davis faculty, also serves as Chief Technology Officer at SynapSense. While SynapSense’s licensing arrangement allows the firm to exploit the fruits of university research, that function is also served by Dr. Pandey’s day-to-day integration with the firm. At a macro level, this integration illustrates important principles about how technical knowledge moves between organizations.

University technology transfer—the process by which university discoveries are transferred to private firms for commercialization—has become a key governmental, academic, and industrial priority. Policy makers see solutions to many of society’s most pressing problems, from cancer to climate change, in scientific research. Technological innovation is a well-recognized driver of economic growth and has gained particular attention in today’s economically challenging times. The importance of technology transfer is all the more apparent given that only about 50 percent of all patented inventions (including those arising from university research) ultimately achieve commercialization. The Supreme Court has even taken an interest in technology transfer, recently deciding a case about the ability of university inventors to assign federally financed inventions to private companies.

In general, technology transfer entails “shifting or relocating discoveries, inventions and innovations from the research laboratory (broadly defined) to


11. It is worth noting that “technology transfer” has myriad definitions across a multitude of fields. See Bozeman, supra note 8, at 630.


the marketplace, and it occurs in a variety of ways. Significant avenues for
technology transfer include scientific publications, presentations at academic
symposia, consulting engagements, informal meetings, placing students in
companies, research contracts, and personal exchanges. These “informal”
mechanisms play a valuable role in disseminating academic technical
knowledge to the private sector for commercialization.

While informal mechanisms are certainly important, this Article focuses
on formal technology transfer in the form of patenting and licensing of
university inventions. Formal technology transfer has attracted significant
academic and policy attention, as it represents an important avenue for
commercializing university inventions and is more amenable to direct legal and
institutional intervention than informal mechanisms. In particular,
commentary has focused on the leading federal statute governing such
activities, the Bayh-Dole Act. Under Bayh-Dole, government contractors
may, upon satisfying certain conditions, take title to patents arising from
taxpayer-financed research. For example, if a university researcher uses funds
from the National Institutes of Health (NIH) to develop a patented invention,
the university (rather than NIH) may take title to that patent. Congress
enacted the Bayh-Dole Act on the belief that allowing universities to patent and
license federally funded inventions would enhance technology transfer to the
private sector, thus promoting commercialization.

This Article applies the lens of industrial organization to shed new light
on formal technology transfer. In so doing, it draws upon (and synthesizes) two
underutilized resources for understanding transfer activities: tacit knowledge
and the theory of the firm. In particular, this Article uses these resources to
examine the intersection of three modalities of technology transfer: markets,
relationships, and organizations. In many ways, the Bayh-Dole Act and the rise

15. Harry Irwin & Elizabeth More, Technology Transfer and Communication: Lessons from
Silicon Valley, Route 128, Carolina’s Research Triangle, and Hi-Tech Texas, 17 J. INFO. SCI. 273, 274
16. See Ajay Agrawal, University-to-Industry Knowledge Transfer: Literature Review and
Transfer]; Lee, Technology Transfer, supra note 7, at 849.
17. See, e.g., Bhaven N. Sampat, Patenting and US Academic Research in the 20th Century:
The World Before and After Bayh-Dole, 35 RES. POL’Y 772, 773–74 (2006); Annetine C. Gelijns &
Samuel O. Thier, Medial Innovation and Institutional Interdependence, 287 JAMA 72, 75 (2002);
18. See, e.g., ASS‘N OF UNIV. TECH. MANAGERS, AUTM U.S. LICENSING ACTIVITY SURVEY
20. See infra Part I.A.
21. This assumes that the university researcher has validly assigned his or her rights in
the invention to the university, an issue recently examined by the Supreme Court. See Bd. of Trs. of
Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc., 131 S. Ct. 2188 (2011). Under the Bayh-
Dole Act, while title to the patent vests in a contractor, the federal government retains certain rights in
22. See infra Parts II & III.
of university patenting reflect a market-oriented model of technology transfer in which universities license inventions to firms in discrete market transactions. However, licensing alone is ill-equipped to transfer tacit, personal knowledge that is highly useful to exploiting patented inventions, thus leading licensees to develop direct relationships with faculty inventors. At the far end of the spectrum, these relationships can mature into varying degrees of organizational integration whereby inventors are brought in-house into firms licensing their patents. These relational and organizational ties represent a critical and underappreciated facet of formal technology transfer.23

This Article unfolds in six parts. Part I explores the predominant, market-oriented conception of university-industry technology transfer. Within this model, patents “commodify” academic inventions and enable market-based transfers to commercial firms. This traditional view presumes that patents adequately “disclose” their technologies, thus rendering licensing of patent rights tantamount to transferring a technology. Part II challenges and refines this market conception by developing a more complete descriptive account of formal technology transfer. In particular, it explores the importance of tacit, uncodified knowledge and relationships between academic inventors and licensees in effectively transferring patented inventions.24 Extending beyond personal relationships, Part III then turns to the theory of the firm to highlight the importance of organizational integration in transferring tacit knowledge. It argues that the difficulty of transferring tacit knowledge between discrete

23. In examining the role of personal relationships and tacit knowledge in formal technology transfer, it is important to clarify what this Article is not about. This Article does not argue that patents are unimportant to formal technology transfer. Paralleling the logic of the Bayh-Dole Act, exclusive rights may be essential to motivate private investment in commercializing certain university technologies. This Article argues, however, that while patents may be necessary in certain contexts, they are often insufficient to transfer a technology. In many cases, direct inventor involvement and tacit knowledge transfer are critical to the success of formal technology transfer. This Article acknowledges but does not directly focus on the related issue of whether universities—in partial response to the Bayh-Dole Act—engage in too much patenting. As I have argued elsewhere, exclusive rights may be inappropriate for certain (patentable) technologies that can achieve widespread use without them. Furthermore, even where patenting is warranted, universities should utilize nonexclusive and selectively exclusive licensing to balance access objectives with incentives for further development. See Peter Lee, Contracting to Preserve Open Science: Consideration-Based Regulation in Patent Law, 58 EMORY L.J. 889 (2009) (hereinafter Lee, Contracting to Preserve Open Science); Peter Lee, Toward a Distributive Commons in Patent Law, 2009 WIS. L. REV. 917 (2009).


This discussion raises the broader issue of what it means for technology transfer to be “effective.” See Bozeman, supra note 8, at 628 (noting several objectives of technology transfer). For the purpose of this Article, I focus on a widely held conception of “successful” technology transfer as translating university discoveries into applied knowledge and technologies that enhance social welfare through increased functionality, productivity, or efficiency.
parties represents a “transactional hazard” that motivates organizational linkages between licensor and licensee entities.

Returning to empirical findings, Part IV presents a novel descriptive theory of formal technology transfer. It argues that such transfer is often characterized by varying degrees of university-industry organizational integration in parallel to formal patenting and licensing agreements. In this manner, licensee firms can directly absorb academic human capital, thereby facilitating tacit knowledge transfer and commercialization of university inventions. Part V turns from the descriptive to the normative, assessing the roles of relationships and organizational integration in formal technology transfer. It also offers prescriptions for optimizing technology transfer while navigating potentially serious tradeoffs with competing academic values and objectives. Finally, Part VI considers the theoretical implications of tacit knowledge for technology transfer and the organization of technology commercialization activities.25

I. MARKETS: COMMODIFYING AND EXCHANGING TECHNOLOGY

A. Patents, Markets, and Technology Transfer

In large part, formal technology transfer relies on markets to disseminate early-stage inventions from universities to commercial firms. This Section first explores, at a schematic level, the importance of markets in organizing the development and commercialization of academic inventions. It then examines the role of patents in enabling market-based technology transfer and the prevailing view that licensing markets operate fairly efficiently to transfer patented technologies to subsequent parties.

Even after an invention has been created, developing that invention into a commercial product frequently requires significant additional effort, expense, and expertise.26 Viewed through the lens of industrial organization, such development raises classic questions of how to structure commercialization activities. The theory of the firm27 posits two organizational archetypes for translating new inventions into commercial products: (1) vertical integration and (2) market-based production.28 In theory, the various capabilities for


27. See infra Part III.A.

discovering new inventions and developing them into commercial products could be housed in a single, vertically integrated firm. This organizational structure, for example, characterized certain firms in the early- to mid-twentieth century such as AT&T and IBM, which combined “upstream” basic research with “downstream” product development. Alternatively, separate entities could independently perform upstream research and downstream commercialization, relying on markets to transfer intermediate goods (such as precommercial inventions) between them. For example, biotechnology firms often conduct upstream research and license drug precursors to pharmaceutical companies, which develop these precursors into drugs, conduct clinical trials, and market finished products to physicians and patients.

Universities generate significant numbers of early-stage inventions, thus giving rise to similar questions regarding how to organize commercialization efforts. Although it sounds fanciful, universities could in theory vertically integrate with commercial firms, thereby bringing both upstream research and downstream product development under one roof. However, given the sharp institutional, programmatic, and normative discontinuities between universities and commercial firms, such integration is not thought to be desirable or possible. Instead of vertical integration, universities and firms have pursued a market-based approach to commercializing many academic inventions. Within this market-based paradigm, universities and firms remain separate entities. They maintain their respective specialties in academic research and commercialization while relying on markets to facilitate the transfer of early stage technologies from one to the other.

Patents play a key role in facilitating these market exchanges by “commodifying” technology, thus allowing it to be bought and sold in

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31. See infra Part V.C.

32. Cf. Mark G. Edwards, Biotechnology and Pharmaceutical Commercialization Alliances: Their Structure and Implications for University Technology Transfer Offices, in 2 INTELLECTUAL PROPERTY MANAGEMENT IN HEALTH AND AGRICULTURAL INNOVATION: A HANDBOOK OF BEST PRACTICES 1227, 1229 (A. Krattiger et al. eds., 2007) (“Technology transfer offices may be in a position to play a role comparable to biotechnology companies as the licensor to a commercialization partner . . . .”).
markets. As a general matter, one could characterize the Bayh-Dole Act and the rise of university patenting as attempts to facilitate market-based transfer of academic technologies to the private sector for commercialization.

As the Bayh-Dole Act relates to the central topic of this Article, some context is in order. Since the rapid expansion of government science funding following World War II, the federal government has wrestled with the question of who should take title to patents arising from federal funds. Some federal agencies retained title to patents arising from publicly funded research while others allowed grantees (e.g., universities) to take title, keeping only a license for themselves. In the late 1970s, concerns grew that government-owned patents were stifling innovation, as firms would not develop inventions into commercial products without possessing exclusive rights. Empirical evidence that government-owned patents achieved very low commercialization rates fueled these concerns, which were exacerbated by perceptions of lagging economic competitiveness with Europe and Japan.

To spur the commercialization of federally funded inventions, Congress passed the Bayh-Dole Act in 1980. The Act allowed and encouraged small businesses and nonprofits that received government funds to take title to

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33. See James Bessen, Patents and the Diffusion of Technical Information, 86 ECON. LETTERS 121, 125 (2005) [hereinafter Bessen, Patents] (“Indeed, it is often argued that patents facilitate the licensing of technology and promote ‘markets for technology.’”).

34. At first glance, the patenting of university inventions—including those arising from federal funds—seems counterintuitive. Cf. Rebecca S. Eisenberg, Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research, 82 VA. L. REV. 1663, 1668 (1996) [hereinafter Eisenberg, Public Research] (noting the double-subsidy of allowing federal grantees to take title to taxpayer-financed patents). However, the key to understanding federal policy promoting university patenting lies in the role of exclusive rights in encouraging additional investments in developing academic inventions into commercial products.


36. This scenario assumes that a university scientist has validly assigned his or her interest in the invention to the university, a topic the Supreme Court recently addressed in Board of Trustees of Leland Stanford Junior University v. Roche Molecular Systems, Inc., 131 S. Ct. 2188 (2011).

37. Eisenberg, Public Research, supra note 34, at 1691–709.

38. In the 1970s, NASA had a commercialization rate of less than 1 percent for inventions under its free use policy, but 18–20 percent for inventions where contractors controlled patents. Aaron S. Kesselheim & Jerry Avorn, University-Based Science and Biotechnology Products, 293 JAMA 850, 851 (2005). The statistical case in favor of the Bayh-Dole Act is suspect, however, in light of significant selection bias. Eisenberg, Public Research, supra note 34, at 1702–05.


patents arising from federally funded research.\textsuperscript{41} Congress enacted this legislation on the view that exclusive rights were necessary to motivate additional private investment to develop patented inventions into commercial products.\textsuperscript{42} Certain grantees, such as small businesses, could directly commercialize patents. However, for a large class of grantees, notably universities, taking title to federally funded patents was believed to promote commercialization by facilitating technology transfer to the private sector.

By encouraging universities to patent publicly financed inventions, the Bayh-Dole Act implicitly endorses a market-oriented model of technology transfer. The Act aims primarily “to use the patent system to promote the utilization of inventions arising from federally supported research or development.”\textsuperscript{43} Within this framework, allowing small businesses to take title to patents makes intuitive sense, as these commercial entities can develop their inventions into marketable goods. Granting title to universities, on the other hand, seems rather peculiar given that these entities are not in the business of developing commercial products.\textsuperscript{44} The Act implicitly posits that universities can exploit licensing markets with relative ease to transfer inventions to the private sector for commercialization.\textsuperscript{45} In this manner, through voluntary


\textsuperscript{42.} \textit{See Eisenberg, \textit{Public Research}, supra note 34, at 1669.} This is, of course, a highly contested premise. Among other considerations, some university inventions—including certain foundational research tools—do not require additional development for useful exploitation. As such, exclusive rights on these technologies may simply decrease output and increase price with little offsetting social gain. \textit{See supra note 23.}


\textsuperscript{44.} \textit{See Eisenberg, \textit{Public Research}, supra note 34, at 1698–99.}

\textsuperscript{45.} Of course, the situation is a bit more complicated. In large part, the Bayh-Dole Act reflects a policy choice between two less-than-ideal options: while universities are not in the business of commercializing inventions, they may be better situated than government agencies to license technologies to private firms. \textit{Cf. Government Patent Policy (The Ownership of Inventions Resulting from Federally Funded Research and Development): Hearings Before the Subcomm. on Domestic and International Scientific Planning and Analysis of the H. Comm. on Science and Technology, 94th Cong. 647 (1976) (statement of Norman Latker, Patent Counsel, H.E.W., Chairman, Ad Hoc Subcommittee on University Patent Policy, Federal Council for Science and Technology) (“[A] substantial majority of inventive ideas require advocates in order to reach the marketplace, and . . . experience indicates that the inventing organization, if interested, is a more likely advocate than a less proximate and not as equally concerned Government staff.”.”).} Proponents of the Act, including university representatives, cited higher rates of patent licensing by universities relative to government agencies. \textit{Eisenberg, \textit{Public Research}, supra note 34, at 1699; see also S. REP. NO. 96-480, at 29 (1979).} Universities, moreover, were much more likely than federal agencies to license inventions exclusively, which was critical to motivating private investment for further development. \textit{See H. REP. NO. 96-1006, pt. 1, at 27 (1980).} In addition, vesting title in universities would allow those institutions to exploit unique competencies for transferring technologies, a subject this Article explores at length below. \textit{See infra Part II.} At a high level, however, the decision to vest title in universities—
transfers, technologies can be “allocated to their highest value as the marvel of the market works its wonders.”\(^46\) The market not only provides a conduit for technology transfer, it also generates financial incentives that help drive invention and commercialization; under the Bayh-Dole Act, universities and faculty inventors collect royalties from licensing taxpayer-financed inventions.\(^47\)

Ultimately, the logic of the market figured prominently in the Bayh-Dole Act’s genesis and structure. For the framers of the Act, the key to commercializing government-funded inventions lay in providing universities with patent rights that they could then license to private firms.\(^48\) Senator Birch Bayh, a cosponsor of the bill, argued that it would give universities (as well as small businesses) the “incentive to develop and market the inventions that they make.”\(^49\) In this sense, the Bayh-Dole Act demonstrates a deep commitment to licensing markets as conduits for technology transfer. This commitment is manifested in, among other developments, the rise of technology transfer offices (TTOs) at universities; these specialized offices handle the “marketing” of technologies by collecting invention disclosures, coordinating patent prosecution, and negotiating licenses with firms.

In a broader sense, the notion that patents facilitate relatively easy market-based technology transfer is not unique to the Bayh-Dole Act or university licensing. Indeed, many elements of the patent system reflect a similar view that licensing markets work fairly efficiently to transfer patented technologies to higher-valued uses. For example, the perceived robustness of licensing markets informs foundational patent theory. In addition to theories emphasizing ex ante incentives to invent and disclose new technologies,\(^50\) patents have also been justified on the basis of ex post efficiency gains from exclusive rights in inventions.\(^51\) According to “prospect theory,” the grant of an early, broad patent on an invention eliminates wasteful “racing” in which multiple parties simultaneously work to discover and develop the same technological


\(^{47}\) See 35 U.S.C. § 202(c)(7)(B) (Supp. 2009). The percentage of royalties allocated to the inventor varies by institution, but it is common for universities to split net royalty income equally among the inventor, the research department, and the university.


The early grant of exclusive rights thus prevents duplicative effort and enhances overall efficiency.53 Implicit in prospect theory is a belief that licensing markets function fairly efficiently. The theory acknowledges that an initial patentee may not be ideally situated to develop an invention and may instead prefer to license a patent to others.54 The theory goes on to presume that a single patentee can identify a wide range of potential licensees and negotiate agreements with relative ease.55 Indeed, well-functioning licensing markets and low transaction costs are critical to the ex post efficiency gains that prospect theory predicts.

Additionally, in fundamental ways, the presumption of efficient market-based technology transfer informs the structure of patent law itself. In the most direct sense, patents reward invention, not commercialization.56 In fact, one can obtain a patent on an invention without ever building a physical embodiment of it.57 How, then, do patented inventions become commercial technologies? For patentees that do not further develop their inventions themselves, the answer lies in market exchanges, most usually in the form of licensing patents to outside developers.

B. The Adequacy of Technical Disclosure

Related to a market-based model of formal technology transfer is the notion that patents adequately disclose the inventions that they cover.58 While much has been written about patent law’s disclosure requirements,59 their relationship to promoting technology transfer requires some explanation. As a preliminary matter, some technical disclosure is necessary simply to define the

52. Notably, prospect theory parallels prominent arguments in favor of the Bayh-Dole Act. See Kitch, supra note 51, at 287 (addressing government-financed patents and observing that “[t]he prospect function suggests the granting of exclusive licenses of patents (viewed as in need of further development)").
55. Cf. Kitch, supra note 51, at 276. As we will see, commentators have criticized these presumptions. See infra notes 82–84 and accompanying text.
56. See DSL Dynamic Scis. Ltd. v. Union Switch & Signal, Inc., 928 F.2d 1122, 1126 (Fed. Cir. 1991) (holding that an invention need not be commercially satisfactory in order to be “reduced to practice” and thus eligible for patenting); Sichelman, supra note 50, at 343–44.
57. See, e.g., Hybritech Inc. v. Monoclonal Antibodies, Inc., 802 F.2d 1367, 1376 (Fed. Cir. 1986). Indeed, certain aspects of patent law, such as public use statutory bars, provide an incentive for inventors to patent very early-stage inventions. See 35 U.S.C. § 102(b) (2006); Christopher A. Cotropia, The Folly of Early Filing in Patent Law, 61 HASTINGS L.J. 65, 72–82 (2009); Sichelman, supra note 50, at 343.
58. See Bessen, Patents, supra note 33, at 121.
invention being transferred, a function performed by the patent claims. More broadly, however, the degree of disclosure in a patent, in terms of both the amount and type of information disclosed, can radically impact the cost of transfer.

In general, formal technology transfer encompasses two related transactions: a legal transaction, in which the licensee obtains the patentee’s authorization to practice some invention, and a cognitive transaction, in which the licensee understands and appropriates the new technology. Most discussions of formal technology transfer focus on the former. However, given that a patent license is “nothing more than a promise by the licensor not to sue the licensee,” this transaction may not in and of itself transfer a technology. After all, obtaining the bare legal right to practice some invention is rather empty unless the licensee actually understands the technology and can practice it.

In theory, the disclosure requirements of patent law satisfy this cognitive transaction by ensuring that a licensee receiving rights to a patented invention can actually make and use it. Of course, disclosure is a requirement of obtaining a patent in the first place and is not a requirement of any specific transaction involving a patented invention. Nonetheless, the adequacy of ex ante disclosure is crucial to lowering the costs of subsequent technology transactions. In the absence of such disclosure, technology deals would have to encompass a much more complicated set of cognitive transactions in which the patentee would communicate complex technical information to the licensee. Adequate patent disclosure thus facilitates discrete, low-cost, arm’s-length transactions between strangers, thereby enabling market-based technology transfer. Importantly, “codification results in commodification of knowledge, allowing it to be treated more as an object of trade or exchange.” Through codification, technical knowledge “need not be developed internally; it can be purchased.”

The requirement that patents adequately disclose their inventions has solid statutory and doctrinal foundations. According to the Patent Act:

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full,

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60. This is not simply achieved, however, as patent claims are notoriously indeterminable. See Dan L. Burk & Mark A. Lemley, Fence Posts or Sign Posts? Rethinking Patent Claim Construction, 157 U.PA.L.REV. 1743, 1744-46 (2009).
64. Robin Cowan & Dominique Foray, The Economics of Codification and the Diffusion of Knowledge, 6 INDUS. & CORP. CHANGE 595, 597 (1997); see Scott Shane, Selling University Technology: Patterns from MIT, 48 MGMT. SCI. 122, 124 (2002) [hereinafter Shane, Selling University Technology].
clear, concise, and exact terms as to enable any person skilled in the art
to which it pertains, or with which it is most nearly connected, to make
and use the same, and shall set forth the best mode contemplated by
the inventor of carrying out his invention.65

This provision establishes three distinct disclosure requirements66: the patent
must provide a written description of the invention,67 enable a person having
ordinary skill in the art (PHOSITA) to make and use it,68 and disclose any best
mode known to the inventor for practicing it.69

These disclosure requirements play an important role in “teaching”
PHOSITAs to practice patented inventions.70 The written description
requirement aims to ensure that the public receives “meaningful disclosure in
exchange for being excluded from practicing the invention for a limited period
of time.”71 Professors Dan Burk and Mark Lemley note “the underlying
assumption . . . that the inventor ‘has’ the invention mentally, and so can give a
sufficiently detailed description of that inventive conception—[thus] physically
creating the invention is straightforward.”72 Perhaps more importantly, the
enablement requirement compels patentees to teach technical artisans how to
make and use their inventions.73 For its part, the best mode requirement
prevents patentees from retaining valuable knowledge about their inventions as
trade secrets.74 In its ideal form, patent disclosure creates an “invisible college
of technology” that allows artisans to understand and practice new inventions.75

66. See generally Timothy R. Holbrook, Possession in Patent Law, 59 SMU L. REV. 123,
67. See Ariad Pharmaceuticals, Inc. v. Eli Lilly & Co., 598 F.3d 1336 (Fed. Cir. 2010) (en
banc) (clarifying that 35 U.S.C. § 112 contains separate enablement and written description
requirements).
68. If a PHOSITA must engage in “undue experimentation” to practice a claimed invention,
the claim fails the enablement requirement. See In re Wands, 858 F.2d 731 (Fed. Cir. 1988).
69. See Chemcast Corp. v. Arco Indus., 913 F.2d 923 (Fed. Cir. 1990). The recently enacted
Leahy-Smith America Invents Act weakens this best mode requirement. While disclosure of any
known best mode is still a formal requirement of patentability, failure to disclose a best mode is no
longer a ground for invalidating a patent in litigation or reexamination proceedings. Pub. L. No. 112-
70. See Liardet v. Johnson (1778) 62 Eng. Rep. 1000 (K.B.) (emphasizing the importance of
technical disclosure as part of the quid pro quo of the patent system); Kewanee Oil Co. v. Bicron
Corp., 416 U.S. 470, 484 (1974); J.E.M. Ag Supply Inc. v. Pioneer Hi-Bred Int’l Inc., 534 U.S. 124,
142 (2001); ROBERT PATRICK MERGES & JOHN FITZGERALD DUFFY, PATENT LAW AND POLICY:
CASES AND MATERIALS 265 (5th ed. 2011); Holbrook, supra note 66, at 126–31.
TECH. L.J. 1155, 1174 n.77 (2002).
73. See Enzo Biochem, Inc., 323 F.3d at 982 (Rader, J., dissenting from denial of rehearing en
banc) (characterizing enablement as “arguably the most important patent doctrine after obviousness”).
74. Chemcast Corp., 913 F.2d at 930; White Consol. Indus., Inc. v. Vega Servo-Control, Inc.,
713 F.2d 788, 791 (Fed. Cir. 1983).
75. Carolyn C. Cooper, Nineteenth-Century American Patent Management as an Invisible
College of Technology, in LEARNING AND TECHNOLOGICAL CHANGE 40, 40 (Ross Thompson ed.,
1993).
As a result, these disclosure requirements significantly reduce the cost of technology transfer. Technical disclosure ensures that patent licensing proceeds solely as a “legal” transaction rather than also encompassing a more complex and costly “cognitive” one. Put differently, to the extent that a patent “embodies” an invention through its technical disclosure, transferring patent rights effectively transfers the technology. The notion of robust disclosure, moreover, reinforces the predominant market-oriented conception of technology transfer. The written description, enablement, and best mode requirements imply that licensees (who are presumed to possess at least the level of ordinary skill in an art) can use patented technologies without undue experimentation.

C. Traditional Critiques of Market-Oriented Technology Transfer

Of course, this classic model of market-oriented technology transfer and the presumptions upon which it rests have not gone uncriticized. First, the perceived robustness of technology markets has lost significant luster in light of increased attention to transaction costs. Much early theoretical work presumed that technology transfer “has no real cost and amounts to little more than the permission to infringe patents.” However, scholars have challenged this view of transactions “as a series of frictionless resource transfers—routine, inevitable, unremarkable.” Indeed, costs related to identifying relevant parties, valuing technologies, and negotiating deals can significantly increase the expense, complexity, and duration of technology transactions. Additionally, strategic behavior, which some commentators explicitly recognize as a transaction cost, can also burden transactions. Strategic behavior is particularly prevalent in situations of bilateral monopoly, which are typical of licensor-licensee negotiations. One study of international technology transfer estimated that transaction costs ranged from 2 to 59 percent of project costs and averaged 19 percent of total costs.

79. See, e.g., Carol M. Rose, The Shadow of The Cathedral, 106 YALE L.J. 2175, 2184 (1997) (distinguishing Type I transaction costs, which relate to assembling large or indefinite groups of parties, from Type II transaction costs, which encompass the actual costs of bargaining, such as strategic behavior).
Transaction costs also inform critiques of prospect theory. Professor Mark Lemley, for example, questions the capacity of a single entity to coordinate the development of an early-stage technological prospect; the range of potential uses and users of such a technology is simply too broad for a single party to manage. Transaction costs have also informed broader structural critiques of patent law. For instance, commentators have questioned unfettered reliance on the market to translate patented inventions into commercial products, advocating more direct intervention to promote commercialization. These transaction-cost critiques apply equally to university-industry technology transfer, which often proceeds on the presumption that a university can identify licensees and transfer technologies at relatively low cost.

Second, commentators have challenged the robustness of patent disclosure, which is a key contributor to efficient technology markets. Courts and scholars note that the teaching function of patents is quite limited; patent law does not require that inventors disclose every last detail of their inventions, and patent specifications are not intended to be production specifications. While the enablement requirement guards against “undue experimentation,” it is permissible for a PHOSITA to have to engage in some experimentation in order to practice a patent. Patent disclosures are notoriously rife with jargon and formalism, which may render them difficult to comprehend. Turning to


83. Lemley, Ex Ante Versus Ex Post, supra note 82, at 135; see Sichelman, supra note 50, at 343–44 (“[O]ften this coordination fails to occur because of high bargaining costs or strategic behavior, which can stymie the independent commercialization efforts of more efficient firms.”); see also Merges & Nelson, supra note 82, at 871–74 (arguing that granting early, broad patents on “technological prospects” may actually undermine innovation); Lemley, Ex Ante Versus Ex Post, supra note 82, at 148–49 (arguing that patent law should provide ex ante incentives to invent but not ex post incentives to advance commercialization).


85. Holbrook, supra note 66, at 132–46; see Bessen, Patents, supra note 33, at 122 (collecting sources).

86. In re Gay, 309 F.2d 769, 774 (C.C.P.A. 1962); see CFMT, Inc. v. YieldUP Int’l Corp., 349 F.3d 1333, 1338 (Fed. Cir. 2003) (“Title 35 does not require that a patent disclosure enable one of ordinary skill in the art to make and use a perfected, commercially viable embodiment . . . .”).

87. See supra note 68.

88. Furthermore, patent disclosures may contain “prophetic examples” of inventions that have never actually been practiced. See In re Strahilevitz, 668 F.2d 1229 (Fed. Cir. 1982).

strategic considerations, patentees have strong incentives to provide vague, narrow disclosures that reveal as little information as possible to competitors and the public at large while preserving maximum claim scope. These deficiencies have motivated several proposals to shore up the disclosure requirements so that they better serve their intended teaching functions.

Notwithstanding these limitations, the market-oriented conception of technology transfer holds much sway. The notion that universities can use licensing markets relatively easily to transfer technologies informed the enactment of the Bayh-Dole Act as well as the rise of an enormous amount of technology transfer infrastructure on university campuses. Indeed, commentators sometimes regard “patenting and licensing” as virtually synonymous with “technology transfer.” Traditional critiques of transaction costs tend to focus on activities leading up to and including the transfer of patent rights, such as identifying licensees, negotiating deals, and safeguarding against strategic behavior. While licensing arrangements often involve ongoing relationships between licensors and licensees to monitor development efforts and determine royalties, these critiques implicitly presume that once patent rights are safely exchanged, technology transfer has occurred. For their part, critiques of patent disclosure have typically focused on general impoverishment of the public domain due to suboptimal disclosure rather than difficulties faced by actual licensees in practicing licensed patents. This Article, however, addresses a qualitatively different type of transaction cost—namely, the cost of exchanging uncodified knowledge—that ultimately calls into question the sufficiency of patents and licenses to transfer technology. The next Part begins this exploration by examining the critical role of relationships and tacit knowledge in academic technology transfer.

90. See Brenner v. Manson, 383 U.S. 519, 534 (1966) (acknowledging “the highly developed art of drafting patent claims so that they disclose as little useful information as possible—while broadening the scope of the claim as widely as possible”); Seymore, supra note 89, at 634–36; Fromer, supra note 89, at 552.

91. See, e.g., Seymore, supra note 89, at 641–57 (arguing that patentees should be required to disclose “working examples” of their inventions); Fromer, supra note 89 at 573–79 (offering several recommendations, including employing “useful redundancy,” utilizing dynamic models, and insisting on a best exemplar in disclosures).


93. See, e.g., Lemley, Economics of Improvement, supra note 78, at 1053–61.

94. See id. at 1053.

95. See, e.g., Fromer, supra note 89, at 547–50; Seymore, supra note 89, at 624.
II. RELATIONSHIPS: PERSONAL CONNECTIONS, TACIT KNOWLEDGE, AND THE IMPORTANCE OF PROXIMITY

While markets are undoubtedly critical to transferring technologies, this Part explores the centrality of personal relationships to formal university-industry technology transfer. In so doing, it draws on empirical work as well as insights from science and technology studies ("STS") to challenge the market-oriented model of technology transfer that dominates much legal scholarship on licensing. It reveals that licensing markets for university inventions are strikingly “thin” and that personal relationships between industry and university personnel—including faculty inventors—are critical to identifying licensees. More importantly, once a licensee has been identified, personal relationships are crucial to the actual process of transferring technology itself. Inventors retain highly valuable “tacit” knowledge regarding their inventions, and direct relationships with inventors represent the most effective conduit for transferring this knowledge to licensees.

A. Identifying Licensees Through Personal Connections

Licensing patented university inventions is difficult. Among the many challenges of university-industry technology transfer is identifying firms willing to license academic inventions. Within a market-based conception of technology transfer, one might imagine that universities simply put their patented inventions “on the market” and wait for potential licensees to walk through the door. Indeed, some universities adopt an “if we build it they will come” strategy for marketing patented inventions. However, this approach
does not comport with a significant proportion of formal technology transfer between universities and industry.

To begin, the market for licensing university technologies is strikingly thin. One survey found that only 22 percent of executed university licenses had multiple bidders.101 In another survey, 44 percent of university technology transfer office (TTO) personnel indicated that bidding on a technology by more than one firm occurred “rarely or never,” while 51 percent stated that it occurred “sometimes.”102 Thus, setting aside “lemons” that generate no commercial interest whatsoever, within the subset of university inventions that do attract interest, overwhelmingly only one firm submits a license offer.103

Given the scarcity of potential suitors for university inventions, personal relationships are critical to identifying licensees. Formally, the responsibility for marketing most university inventions falls on TTOs.104 While TTOs engage in broad-based advertising, personal contacts of individual TTO officers play a crucial role in identifying prospective licensees.105

Notably, academic inventors themselves are often critical to identifying licensees.106 Within a traditional schematic division of labor, faculty inventors disclose inventions to a TTO, assist in drafting patent applications, and then leave marketing, prosecution, and licensing to TTO personnel while returning to their academic research. In reality, however, inventors are intensely involved in marketing their inventions: according to one survey, inventors across six academic institutions contributed 54 percent of the leads for executed

101. Jensen & Thursby, supra note 6, at 245.
102. Thursby & Thursby, Are Faculty Critical?, supra note 96, at 166.
103. Licensing markets for patented university inventions are plagued with a high degree of uncertainty. Among other considerations, there is great technical and business uncertainty regarding whether an embryonic technology can become a viable commercial product. Additionally, there is legal uncertainty to the extent that a significant portion of granted patents are technically invalid. See John Allison & Mark A. Lemley, Empirical Evidence on the Validity of Litigated Patents, 25 AIPLA Q.J. 185, 196 (1998) (finding that from 1989 to 1996, courts held patents invalid in approximately 50 percent of cases where validity was at issue and decided).
104. Indeed, the Bayh-Dole Act was justified in part on the expectation that vesting title in universities would encourage them to advertise federally funded inventions to industry. See Jeannette Colyvas et al., How Do University Inventions Get Into Practice?, 48 MGMT. SCI. 61, 62 (2002) [hereinafter Colyvas et al., How Do University Inventions Get into Practice?]. Such specialized institutions can, in theory, significantly lower the cost of transferring technologies to outside parties. Cf. Eric von Hippel, “Sticky Information” and the Locus of Problem Solving: Implications for Innovation, 40 MGMT. SCI. 429, 431 (1994). Early identification of licensees is all the more important because many universities only apply for patent protection after a licensee is secured and can help pay for patent prosecution. Jensen & Thursby, supra note 6, at 244; Siegel et al., Effective Transfer, supra note 5, at 118.
105. Jason Owen-Smith & Walter W. Powell, Networks and Institutions, in SAGE HANDBOOK OF ORGANIZATIONAL INSTITUTIONALISM 596, 614 (Royston Greenwood et al., eds., 2008); see Siegel et al., Effective Transfer, supra note 5, at 121.
licenses.\textsuperscript{107} Given the specific competencies and incentives at play, academic inventors are well positioned to help advertise their inventions. Inventors are highly knowledgeable about their technical areas and thus are well suited to recognize opportunities for commercial exploitation.\textsuperscript{108} Furthermore, under the Bayh-Dole Act, inventors share in royalties and therefore have an incentive to promote commercialization of their technologies.\textsuperscript{109}

The critical role of faculty inventors in marketing their discoveries, moreover, suggests that TTOs often play slightly different roles in technology transfer than commonly perceived. TTOs frequently do not create linkages between academia and industry so much as manage relationships between parties who already know each other.\textsuperscript{110} In some ways, the formalized advertising of inventions by TTOs merely supplements the informal networks of individual inventors. Accordingly, formal TTO marketing is particularly important for inventions that generate little immediate industry interest,\textsuperscript{111} perhaps because of a lack of personal connections on the part of the academic inventor.

The picture that emerges is very different from what a market-oriented conception of technology transfer would suggest. Patented university inventions are not well-recognized commodities that attract a thick set of potential buyers. Universities struggle to find licensees for their inventions and must often rely on personal relationships to supplement broad-based marketing. Notably, inventors themselves play an indispensable role in identifying licensees based on personal contacts.

\section*{B. Tacit Knowledge}

In addition to identifying potential commercial partners, faculty inventors are also critical to transferring patent-related technical knowledge to licensees. In the traditional view, technology transfer unfolds as a discrete market transaction in which a patent owner (who need not be the actual inventor) exchanges legal rights for consideration. Undergirding this regime is the notion that the patent itself effectively discloses the invention.\textsuperscript{112} However, even

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\item \textsuperscript{107} C. Jansen & H.F. Dillon, \textit{Where Do the Leads for Licenses Come From? Source Data from Six Institutions}, 14 INDUSTRY & HIGHER EDUC. 150 (2000).
\item \textsuperscript{108} Andy Lockett et al., \textit{Technology Transfer and Universities’ Spin-Out Strategies}, 20 SMALL BUS. ECON. 185, 188 (2003).
\item \textsuperscript{109} \textit{See supra} note 47. As will be discussed, royalty income is not the only way that faculty inventors can financially benefit from their patented technologies.
\item \textsuperscript{110} Colyvas et al., \textit{How Do University Inventions Get into Practice?}, \textit{supra} note 104, at 65.
\item \textsuperscript{111} \textit{Id.} at 67.
\item \textsuperscript{112} \textit{See supra} Part I.C. In the academic context, patents are often supplemented by scientific articles that also describe a particular discovery. See Fiona Murray & Scott Stern, \textit{Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-commons Hypothesis}, 63 J. ECON. BEHAV. & ORG. 648 (2007) (describing “patent-paper pairs,” in which a scientist discloses a discovery both in a patent and in an academic article). For the same
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where patent disclosure satisfies statutory and doctrinal requirements, it is often incomplete. In particular, much useful knowledge about patented inventions remains “tacit” or personal to the inventor. Transferring this tacit knowledge represents a central challenge of university-industry technology transfer.

As philosopher of science Michael Polanyi\(^{113}\) famously observed, “We can know more than we can tell.”\(^{114}\) Indeed, much scientific and technical knowledge is tacit. In general, tacit knowledge is personal to an individual and not subject to codification. For example, tacit knowledge encompasses all of the subtle experiential elements of cooking a gourmet dish that a master chef knows but cannot describe in a written recipe.\(^{115}\) In the technical context, tacit knowledge refers to implicit know-how,\(^{116}\) perhaps related to a discovery or invention, that a scientist cannot easily articulate in text.\(^{117}\) It represents “intangible knowledge, such as rules of thumb, heuristics, and other ‘tricks of the trade.’”\(^{118}\) As Polanyi notes, tacit or “indefinable” knowledge plays a particularly important role in technology.\(^{119}\) Indeed, commentators have characterized technology as a “complex mix of codified data and poorly defined, tacit ‘know-how.’”\(^{120}\)
In many ways, tacitness is a question of degree. At one end of the spectrum lies “purely tacit” knowledge that is not capable of codification. However, much tacit knowledge is “latent”: it is technically codifiable but remains uncodified. In some cases, codification may be cost prohibitive. In other cases, codification costs may be surmountable, but the originator of some new knowledge does not perceive any market demand or social need to translate personal knowledge to text. Finally, self-interested behavior may motivate deliberate concealment of knowledge that could otherwise be codified. Taking all of these factors into account, for the purposes of this Article, I adopt an expansive conception of tacit knowledge that equates it with uncodified rather than uncodifiable knowledge.

Importantly, “tacitness” has a dynamic quality. In the scientific context, knowledge relating to a pioneering discovery may initially have a high tacit dimension, as only a small community of researchers (or, perhaps, only the discoverer himself or herself) can understand, articulate, and reproduce it. However, path-breaking discoveries ultimately become widely accepted conventions, and knowledge tends to become less tacit over time.

Almost by definition, tacit knowledge is very difficult to communicate. Codification is a process of packaging knowledge into readily understandable bits, thus facilitating its low-cost dissemination. Tacit knowledge, however, does not reside in texts but in “people, institutions or routines.” As Professor Dan Burk observes, “codified knowledge, having been separated from human
memory, may be more readily moved about, but the uncodified knowledge that
supports this codified knowledge moves only with the humans who carry it, or
sometimes not at all.”129 Notably, the disclosure doctrines of patent law may be
understood as requiring the codification of otherwise tacit knowledge, thus
enabling its low-cost transmission.130

Particularly important for present purposes, tacit knowledge is often
critical for effective technology transfer.131 Importantly, this is true even where
an inventor has “codified” an invention through patenting.132 As discussed
above, codification via patenting is often incomplete because of doctrinal
design,133 prohibitive cost,134 strategic behavior,135 or some combination
thereof. As such, tacit knowledge residing in the mind of an inventor may be
quite important to successfully transferring a patented technology. Along these
lines, patent licensees recognize that “the aggregate value of all the ‘minor’
improvements, tweaks, and accumulated operational wisdom [related to a
patent] often exceeds the value of the basic invention itself.”136 Indeed, private
companies often seek to license tacit knowledge along with related patents.137

Because of the early-stage nature of academic inventions, tacit knowledge
is particularly crucial to university-industry technology transfer.138 The

129. Burk, Knowledge Codification, supra note 63, at 1017.
130. Id. at 1012; see supra notes 85–91 and accompanying text.
131. See Agrawal, Engaging the Inventor, supra note 122, at 65 (noting the value of latent
knowledge); Arora, Contracting for Tacit Knowledge, supra note 118, at 234 (noting the importance
of tacit knowledge in technology transfer generally and its particular importance to transferring
technologies to developing countries); Arora, Licensing Tacit Knowledge, supra note 76, at 42, 54
(“Utilizing technology requires a great deal of know-how.”); Jonathan M. Barnett, Intellectual
Property as a Law of Organization, 84 S. Cal. L. Rev. 785, 801–02 (2011) [hereinafter Barnett,
Organization] (discussing “information opacity”); Bozeman, supra note 8, at 642 (summarizing one
study concluding that “the extent of transfer of tacit knowledge often has a major impact on the
effectiveness of manufacturing technology transfer”); Howells, Technology Transfer, supra note 117,
at 97 (“[T]acit knowledge has been a key barrier in the diffusion of technological innovation.”).
132. Cowan & Foray, supra note 64, at 599 (noting that tacit knowledge is often necessary to
exploit codified knowledge).
133. In re Gay, 309 F.2d 769, 774 (C.C.P.A. 1962) (observing that patents are not intended to
be product specifications).
134. Burk, Knowledge Codification, supra note 63, at 1014. Interestingly, the patent system
implicitly recognizes the difficulty of codifying technology by allowing physical deposit of an
invention to satisfy the disclosure requirements of patentability. See In re Wands, 858 F.2d 731 (Fed.
Cir. 1988) (discussing physical deposit); Lynne G. Zucker et al., Commercializing Knowledge:
University Science, Knowledge Capture, and Firm Performance in Biotechnology, 48 MGMT. SCI.
138, 142 (2002) [hereinafter Zucker et al., Commercializing Knowledge].
135. See supra note 83.
136. Merges, Transactional View, supra note 77, at 1501.
137. See infra Part III. Notably, the importance of tacit knowledge in commercializing
patented inventions helped justify provisions of the Bayh-Dole Act allowing small businesses (rather
than government agencies) to retain title to patents arising from federally funded research. These
businesses were likely to possess tacit knowledge related to the invention at issue, thus making them
ideal candidates to lead commercialization efforts. Eisenberg, Public Research, supra note 34, at 1697.
138. Agrawal, Knowledge Transfer, supra note 16, at 293; Kwanghui Lim, The Many Faces of
Absorptive Capacity: Spillovers of Copper Interconnect Technology for Semiconductor Chips, 18
“tacitness” of knowledge increases as a function of novelty and complexity, and the most pioneering academic breakthroughs often arise first in tacit form. According to one study, at the time of licensing, over 75 percent of university inventions were no more than a proof of concept or lab-scale prototype. At that time, only 12 percent were ready for commercial use, and manufacturing feasibility was only known for 8 percent of these inventions. In another study, only 7 percent of licensed technologies were deemed ready for practical or commercial use, and 40 percent were simply a proof of concept. Indeed, the early-stage status of university inventions contributes to lower commercialization rates relative to nonuniversity inventions.

Of course, the importance of tacit knowledge to technology transfer depends on the nature of the invention at issue. Tacit knowledge is most relevant for university inventions that are highly embryonic. Additionally, some technologies may be more inherently understandable and thus easier to transfer. For example, tacit knowledge may be less relevant for certain university-invented research tools that members of the scientific community can use “off the shelf.” There may be field-specific differences as well. Some commentators suggest that tacit knowledge may be particularly pertinent to engineering and computer science inventions. On the other hand, patenting and licensing alone may be sufficient to transfer some kinds of biotechnology and pharmaceutical inventions, which tend to be more mature and more easily

139. Zucker et al., Commercializing Knowledge, supra note 134, at 140–41.
140. Jensen & Thursby, supra note 6, at 243.
141. Id.
142. Thursby & Thursby, Are Faculty Critical?, supra note 102, at 167.
143. Id. In debates leading to the Bayh-Dole Act, policy makers characterized university inventions as particularly risky because of their close proximity to basic research and relative distance from commercial applications. Eisenberg, Public Research, supra note 34, at 1699.
144. See Ajay Agrawal, Technology Acquisition Strategy for Early-Stage Inventions: Measuring the Importance of Engaging the Inventor 21 (June 22, 2002) (unpublished manuscript) (on file with the California Law Review) [hereinafter Agrawal, Technology Acquisition Strategy]; Zucker et al., Commercializing Knowledge, supra note 134, at 141; Cowan & Foray, supra note 64, at 595; cf. Bessen, Communicating Technical Knowledge, supra note 33, at 3–4 (noting that in the early stages of many technologies, knowledge is communicated via costly personal interactions). Along these lines, licensing is generally adequate to “transfer of older, simpler, more codified technology.” Oxley, supra note 120, at 405.
146. See Lee, Contracting to Preserve Open Science, supra note 23, at 892 (discussing research tools).
147. See Agrawal, Technology Acquisition Strategy, supra note 144, at 21. But see Rai et al., supra note 96, at 1551 (suggesting that software inventions tend to be more highly codified relative to life sciences inventions).
codified than other types of university inventions. However, even for these technologies, the effective communication of tacit knowledge is likely to accelerate downstream appropriation.

The personal, experiential nature of tacit knowledge gives rise to the challenge of how to best convey it, as traditional avenues for disseminating (codified) knowledge are inadequate. Because transmitting tacit knowledge “requires, almost by definition, face-to-face contact,” the primary vehicle for transmitting such knowledge is people. Unlike codified knowledge, tacit knowledge remains “sticky” and personal to the academic inventor. The significant value of tacit knowledge thus encourages direct interaction between academic inventors and firms that license their patents. Accordingly, unlike one-off market transactions, technology transfer typically unfolds as a “contact sport.”

Empirical studies underscore the importance of ongoing involvement by faculty inventors in university-industry technology transfer. In one survey of technology transfer stakeholders, 70 percent of entrepreneurs cited “informal transfer of know how” as an output of university technology transfer. In a survey of TTOs at sixty-two U.S. research universities, respondents estimated that 71 percent of inventions licensed could not be successfully commercialized.


149. Arora, Contracting for Tacit Knowledge, supra note 118, at 235; see Howells, Technology Transfer, supra note 117, at 93 (“Above all, there are no clear market mechanisms which facilitate the transfer of tacit knowledge directly or by which it can be adequately measured.”); Shane, Selling University Technology, supra note 64, at 124 (“When information is tacit, it must be transferred through interpersonal contact, and economic actors must develop relationship-specific assets to facilitate that transfer.”); Oxley, supra note 120, at 393 (“Tacit knowledge is extremely difficult to transfer without intimate personal contact, involving teaching, demonstration, and participation.”); see Cowan et al., supra note 113, at 215 (describing the development of the TEA laser and observing that “none of the research teams which succeeded in building a working laser had done so without the participation of someone from another laboratory where a device of this type already had been put into operation”); H.M. Collins, The TEA Set: Tacit Knowledge and Scientific Networks, 4 SCI. STUD. 165 (1974). In the biotechnology arena as well, transferring tacit knowledge often requires hands-on work with novices. Zucker et al., Commercializing Knowledge, supra note 134, at 141.

150. Cf. Kogut & Zander, supra note 126, at 389 (“To facilitate this communication [of technical information], certain individuals play pivotal roles as boundary spanners, both within the firm as well as between firms.”).

151. Cowan & Foray, supra note 64, at 598.

152. Agrawal, Engaging the Inventor, supra note 122, at 65; see Mansfield, supra note 4, at 64.

153. Agrawal, Engaging the Inventor, supra note 122, at 65 (quoting the Director of the MIT Technology Licensing Office); see id. at 78 (“Private contracts (or at least relationships) between the acquiring firm and the inventor are required in order to perform the necessary knowledge transfer.”).

154. Siegel et al., Effective Transfer, supra note 5, at 126, 130.
without faculty cooperation in further development.155 Another study found that roughly 40 percent of all licenses required faculty involvement.156 Of course, the ongoing participation of academic inventors in commercialization efforts serves a number of functions, not all of which are related to knowledge transmission. Licensee firms may engage academic inventors for nontechnical reasons, such as to send favorable signals to capital markets.157 Additionally, faculty involvement may be driven not only by licensees, but by faculty inventors themselves; scientists are often psychologically invested in their inventions and actively seek to bring them to market.158 Inventors thus play important roles in “championing” their creations—finding licensees for inventions that do not generate much initial interest and prodding lethargic licensees to aggressively pursue commercialization.159

Nonetheless, the importance of inventor involvement in facilitating tacit knowledge transfer looms large. In some cases, the inventor’s knowledge is helpful in accelerating adoption of a basic patented invention. In other cases, tacit knowledge may be very helpful in extending, adapting, or refining a technology above and beyond the core invention disclosed in a patent.160 While invention-related tacit knowledge is not always difficult to codify or communicate, interpersonal interaction between a licensee and an inventor may be required to elicit it. In particular, side-by-side problem solving and conversation may be necessary for a licensee to articulate a specific technical question or for an inventor to recognize that she possesses relevant “know-how” of value.

Significantly, considerations of tacit knowledge and the importance of engaging faculty inventors even informed the structure of the Bayh-Dole Act. In the hearings leading up to the Act, representatives from academia argued that universities were better conduits for technology transfer than government agencies because they were more familiar with the inventions at issue and had

155. Jensen & Thursby, supra note 6, at 243.
156. Thursby & Thursby, Are Faculty Critical?, supra note 102, at 170. Qualitative accounts corroborate this phenomenon. For example, the ongoing involvement of faculty inventors was critical to developing gallium nitride, a wide band gap semiconductor, as well as the Ames II test, a screening method for determining whether substances have mutagenic properties. DAVID C. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT IN THE UNITED STATES 159–66, 169–76 (2004) [hereinafter MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION]. For extended case studies of inventor involvement in university-industry technology transfer, see infra Part II.B.1.
159. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION, supra note 156, at 155–76.
160. See Agrawal, Engaging the Inventor, supra note 122, at 68.
direct access to faculty inventors. In particular, universities could facilitate the direct interaction between inventors and licensees that is often critical to technology transfer. The availability of royalties, moreover, would induce faculty inventors to continue working on inventions even after they had been licensed to a commercial firm. All of these considerations informed the Act’s overarching policy choice to allocate title to taxpayer-funded inventions to universities rather than federal funding agencies.

These considerations continue to reverberate in contemporary university-industry technology transfer. In biotechnology, for example, an inventor who has genetically modified a cell may be quite helpful in scaling up mass production of the therapeutic protein derived from it. More generally, according to one entrepreneur, “So much of what we call technology transfer is information transfer, knowledge transfer. It’s not something that could immediately be put into a product. It might be something that is a tidbit of knowledge that will help somebody in their development efforts at one of our companies.” Ultimately, tacit knowledge and faculty involvement play central roles in effectively transferring patented university inventions to the private sector for commercialization.

161. See Hearing on Government Patent Policies: Institutional Patent Agreements Before the S. Comm. on Small Bus., Subcomm. on Monopoly & Anticompetitive Activities, 95th Cong. 383 (1978) (statement of Howard W. Bremer, Patent Counsel, Wisconsin Alumni Research Foundation) (“Ownership of the invention by the university brings another asset into the technology transfer picture; namely the active participation of the inventor.”); id. (“The active participation of the university inventor is a prime ingredient in the successful transfer of an invention to the market and generally, a workable and successful technology transfer function at a university will involve the inventor on either a formal or informal basis.”); Eisenberg, Public Research, supra note 34, at 1700.

162. Hearing on Government Patent Policies: Institutional Patent Agreements Before the S. Comm. on Small Bus., Subcomm. on Monopoly & Anticompetitive Activities, 95th Cong. 309 (1978) (statement of Thomas F. Jones, Vice President, Research, MIT) (“Government personnel are in a much less favorable position to ascertain or pursue the commercial marketability of an invention since they cannot be as intimately familiar with the invention as a university inventor himself. Hence, the transfer of necessary know-how would be drastically curtailed.”); id. (“[I]n many cases, the direct interaction between the inventor and his university on the one hand, and the commercial licensee on the other hand is most productive in insuring an effective transfer, since it encourages the free flow of know-how and data which is essential to strengthen and support the licensed invention. Who but the inventor is best-qualified to provide the technological background material and know-how that is needed to enable a licensee to fully develop the invention?”); see supra Part II.

163. See Hearing on Government Patent Policies: Institutional Patent Agreements Before the S. Comm. on Small Bus., Subcomm. on Monopoly & Anticompetitive Activities, 95th Cong. 255 (1978) (statement of Charles H. Herz, General Counsel, National Science Foundation) (“The universities also have a great advantage in dealing with potential licensees that any Government licensing operation would lack: They have the inventor at hand and can readily produce him for prelicense or postlicense consultation. They also can and do command the inventor’s interest by promising him a share of any royalties that ensue.”); Eisenberg, Public Research, supra note 34, at 1700.


165. Siegel et al., Effective Transfer, supra note 5, at 130.
1. Case Studies

The development of the Fluorescence-Activated Cell Sorter (FACS) and Xalatan, a leading glaucoma medication, provide concrete examples of the importance of tacit knowledge transmission to commercializing university technologies.

a. The Fluorescence-Activated Cell Sorter

Tacit knowledge and inventor involvement were critical to developing the FACS.\textsuperscript{166} The FACS is a device that uses fluorescence to rapidly sort cells by “tagging” them with specific surface markers and diverting similarly marked cells into different receptacles.\textsuperscript{167} The device is a foundational research tool in flow cytometry because it allows scientists to rapidly sort cells from an undifferentiated mixture, and it also has wide applications as a diagnostic tool.\textsuperscript{168} Based on work conducted in the 1960s,\textsuperscript{169} Leonard Herzenberg and his colleagues at Stanford University received NIH funds to build a FACS machine.\textsuperscript{170} With NIH’s permission,\textsuperscript{171} members of Herzenberg’s group obtained a patent on the machine in 1974.\textsuperscript{172}

The patent discloses the basic “method and apparatus for physically separating particles such as functionally different cell types.”\textsuperscript{173} While this method and apparatus were technically operational, early prototypes were extremely large (occupying an entire room) and impractical for wide application.\textsuperscript{174} Accordingly, Herzenberg and his colleagues sought a commercial partner to further develop the FACS into a desktop-sized, practical product.\textsuperscript{175} In 1972, these efforts bore fruit when Becton-Dickinson entered into a licensing agreement with Stanford University.

Importantly, Becton-Dickinson explicitly licensed “‘know-how’ related to designing and developing this machine which would be transferred verbally and by demonstration.”\textsuperscript{176} Herzenberg and his colleagues continued to work with Becton-Dickinson, contributing to extensive modifications and refinement

\textsuperscript{166} See Jeanette Colyvas et al., Intellectual Property Rights and Academic Health Centers, in ECONOMICS, LAW, AND INTELLECTUAL PROPERTY: SEEKING STRATEGIES FOR RESEARCH AND TEACHING IN A DEVELOPING FIELD, 155, 166–70 (Ove Granstand ed., 2003) [hereinafter Colyvas et al., Academic Health Centers].
\textsuperscript{167} Id. at 166–67.
\textsuperscript{168} Id. at 167.
\textsuperscript{169} See H.R. Hulett et al., Cell Sorting: Automated Separation of Mammalian Cells as a Function of Intracellular Fluorescence, 166 SCIENCE 747 (1969).
\textsuperscript{170} Colyvas et al., Academic Health Centers, supra note 166, at 167.
\textsuperscript{171} This work preceded the Bayh-Dole Act, when universities seeking to patent the results of NIH-funded research had to seek prior approval from NIH and submit a licensing plan.
\textsuperscript{172} U.S. Patent No. 3,826,364 (filed May 22, 1972).
\textsuperscript{173} Id.
\textsuperscript{174} Colyvas et al., Academic Health Centers, supra note 166, at 167–68.
\textsuperscript{175} Id. at 167–68.
\textsuperscript{176} Id. at 168 (emphasis added).
of the machine.\textsuperscript{177} Herzenberg himself became a consultant to Becton-Dickinson, and he and his staff spent significant time refining the FACS.\textsuperscript{178} Transfer and development of the patented FACS thus relied upon “many other mechanisms of knowledge transfer beyond the actual patent documentation and license agreement . . . .”\textsuperscript{179} For example, feedback from users in the Herzenberg lab was critical; biologists and engineers met both within the lab and at Becton-Dickinson to discuss and further refine the technology.\textsuperscript{180} Furthermore, the Herzenbergs and their colleagues maintained contact with Becton-Dickinson for years as consultants, collaborators, and trainers.\textsuperscript{181} Notwithstanding formal disclosure in a patent, tacit knowledge on the part of faculty inventors was critical to transferring and developing the FACS into a viable commercial product.

\textit{b. Xalatan}

The development of Xalatan, a leading glaucoma medication, further illustrates the importance of faculty involvement in commercialization. Glaucoma, a serious eye disease that may lead to blindness, is characterized by high intraocular pressure. Based on pioneering research in the 1970s and 1980s, Laszlo Bito, a Professor of Ocular Physiology at Columbia University’s College of Physicians and Surgeons, discovered that prostaglandins (PGs) applied directly to eyes could reduce intraocular pressure.\textsuperscript{182} Government grants funded Bito’s research, and pursuant to the Bayh-Dole Act, Columbia University obtained a patent on Bito’s discovery in 1986.\textsuperscript{183} Columbia’s Office of Scientific and Technology Development sought a licensee for the patent, but it was Bito himself, via a personal connection, who introduced the invention to Pharmacia, which ultimately received an exclusive license.\textsuperscript{184}

Importantly, Bito remained engaged with the project after patenting and licensing, and his ongoing participation was crucial to technology transfer to Pharmacia.\textsuperscript{185} In particular, Bito played an important role in overcoming remaining technical hurdles to develop the invention into a marketable treatment. Bito’s patent describes a functional method for using PGs to treat intraocular pressure and details Bito’s experiments on PGs with owl monkeys, cats, and rhesus monkeys.\textsuperscript{186} However, the initial PGs and PG derivatives

\begin{itemize}
\item \textsuperscript{177} \textit{Id.}
\item \textsuperscript{178} \textit{Id. at 168–69.}
\item \textsuperscript{179} \textit{Id. at 168.}
\item \textsuperscript{180} \textit{Id. at 169.}
\item \textsuperscript{181} \textit{Id.}
\item \textsuperscript{182} \textit{See Laszlo Z. Bito, A New Approach to the Medical Management of Glaucoma, from the Bench to the Clinic, and Beyond, 42 INVESTIGATIVE OPHTHALMOLOGY & VISUAL SCI. 1126 (2001).}
\item \textsuperscript{183} \textit{U.S. Patent No. 4,599,353 (filed May 3, 1982).}
\item \textsuperscript{184} \textit{Bito, supra note 182, at 1129.}
\item \textsuperscript{185} \textit{Cf. Colyvas et al., Academic Health Centers, supra note 166, at 169.}
\item \textsuperscript{186} \textit{U.S. Patent No. 4,599,353 (filed May 3, 1982).}
\end{itemize}
encompassed by the patent caused eye irritation and also changed eye color in some animal test subjects. Bito’s intimate knowledge of PGs and their derivatives, as well as his personal experience with eye irritation, played a supporting role in Pharmacia’s identification of the active ingredient in Xalatan, a PG derivative called latanoprost that caused minimal eye irritation.

Bito played an even more instrumental role in assuaging fears over potential changes to eye color through the use of PGs. Responding to a request from Pharmacia, Bito worked “day and night” to learn melanin chemistry and its relevance to PG treatment for intraocular hypertension. Drawing on his understanding of PGs as well as his newfound knowledge of melanin chemistry, Bito revealed that changes in eye pigmentation in humans taking topical PGs had no serious health consequences, thus broadening the consumer appeal of Xalatan. Ultimately, Bito’s personal familiarity with his invention and his continued involvement after patent licensing were critical to the commercialization of this important glaucoma medication.

C. Absorptive Capacity

Further illustrating the significant cognitive challenges of technology transfer is the fact that successful transfer often depends on the “absorptive capacity” of licensee firms. Absorptive capacity refers to the ability of organizations to appropriate and exploit exogenous information. It refers to the internal knowledge base—much of it tacit—that allows a firm to exploit new innovations. The importance of absorptive capacity further challenges a market-based model of technology transfer, for it reveals that academic technologies are not fungible commodities that are easily bought and sold in the market; firms must cultivate their own knowledge base to prepare themselves to receive outside technologies.

188. See id.
189. Id. at 1110.
190. Id. at 1130.
191. Id.
193. Id. at 129.
194. Agrawal, Knowledge Transfer, supra note 16, at 291 (“At a conceptual level, it is interesting to note that the transfer of tacit knowledge, that which is costly or impossible to codify, is at the heart of the majority of [work related to absorptive capacity].”). Along these lines, where firms enjoy high absorptive capacity, their need to appropriate exogenous tacit knowledge related to a particular inventor decreases. See, e.g., MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION, supra note 156, at 155–59 (describing the relatively easy adoption of pioneering techniques of “cotransformation”); id. at 172–76 (describing how the development of soluble CD4, a prototype anti-AIDS drug, did not depend significantly on ongoing inventor involvement).
Firms frequently invest in knowledge, skills, and organizational routines to identify and utilize externally generated knowledge. Firms develop absorptive capacity in several ways. First, they do so by conducting in-house research and development. This helps explain, for example, why firms perform basic research even when the results often fall into the public domain. Second, particularly in science-intensive fields, firms develop absorptive capacity by building connections with the academic research community. Indeed, the ability to engage public-sector research contributes significantly to the productivity of private-sector research. Absorptive capacity is particularly important for firms seeking to exploit foundational academic research given the “basic” nature of such knowledge.

Industry practice illustrates the value of enhancing absorptive capacity through relationships with academia. In the pharmaceutical industry, firm connectedness to the academic community, such as through collaboration and coauthoring scientific articles, is a key determinant of successful drug discovery. Additionally, biotechnology firms approach collaboration—including with academic scientists—as a means of enhancing their capability for learning. The objective of enhancing absorptive capacity represents a primary reason why firms sponsor research at universities and collaborate with academic researchers. The importance of these personal relationships in increasing absorptive capacity challenges market-oriented accounts of technology transfer in which buyers and sellers simply exchange commoditized inventions in the market.


196. Cockburn & Henderson, Coauthoring Behavior, supra note 195, at 158; Cohen & Levinthal, Absorptive Capacity, supra note 192.


198. See, e.g., 1980 GENENTECH ANNUAL REPORT 2 (“While there is a continuing effort to ensure protection of our patentable inventions and know-how, interaction with the broad scientific community is important if we are to remain on the cutting edge of science.”).


200. Cohen & Levinthal, Absorptive Capacity, supra note 192, at 140; Owen-Smith & Powell, supra note 105, at 608 (“The breakneck pace of technical advance had rendered it difficult for any single organization to remain scientifically abreast on multiple fronts, hence linkages to universities at the forefront of basic science have been necessary.”).

201. Lim, supra note 138, at 1278; see Siegel et al., Effective Transfer, supra note 5, at 135.


D. Institutional Decentralization

This relationship-oriented model of technology transfer helps explain some notable features of university patenting and licensing, including the highly decentralized nature of technology transfer infrastructure. Standard economic theory would predict substantial consolidation and outsourcing of technology transfer functions. In particular, prospective efficiency gains from economies of scale and specialization suggest that universities should outsource technology transfer activities to third-party firms, much as they outsource cafeteria services to independent vendors. However, such is not the case in contemporary technology transfer.

In fact, for several decades, much university technology transfer was outsourced and highly centralized. In 1912, Frederick Cottrell of the University of California, Berkeley, established Research Corporation, an independent third-party technology licensing firm. In 1937, Research Corporation negotiated an Invention Administration Agreement with MIT whereby the firm assumed management of the university’s patent portfolio. Building on the success of the MIT agreement, Research Corporation concluded similar agreements with several hundred U.S. universities during the 1940s and 1950s. Among other benefits, Research Corporation prevented a significant amount of redundancy, as its client universities did not need to maintain their own TTOs.

Ultimately, however, the centralized model of patent management embodied in Research Corporation gave way to massive decentralization. While many factors contributed to this development, the local, relational nature of technology transfer was significant. Inventors are critical to many aspects of successful technology transfer, and Research Corporation’s limited ability to interface directly with university inventors ultimately contributed to its downfall. At the same time, the relational nature of technology transfer has helped fuel a proliferation of individual TTOs at university campuses across the country. The number of technology transfer offices at universities, hospitals, and research institutes exploded from 25 in 1980 (the year of Bayh-Dole’s

206. See Koenraad Debackere & Reinhilde Veugelers, The Role of Academic Technology Transfer Organizations in Improving Industry Science Links, 34 RES. POL’Y 321, 325 (2005) (“Universities with a high record in [industry science links] most often apply a decentralized model of technology transfer, i.e. the responsibilities for transfer activities are located close to research groups and individuals.”).

207. Cf. de Larena, supra note 92, at 1439–44 (advocating the establishment of a “unified, national technology-transfer center”).

208. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION, supra note 156, at 60. Interestingly, among other reasons, Cottrell created this independent patenting and licensing firm to insulate universities from the direct influence of commercial interests. See Sampat, supra note 17, at 774–75.

209. Id. at 67.

210. Id. at 64.

211. Id. at 75.
While such institutional redundancy may appear wasteful, it is an outgrowth of the highly personal, local nature of technology transfer.

E. Geographic Clustering

The relational nature of technology transfer is further evident in the geographic clustering of university licensing. The predominant market model of technology transfer predicts the smooth operation of national licensing markets. To the extent that technologies are discrete commodities, transaction costs are low, and technical disclosure is adequate, patent licensing should not correlate with geographic distance. However, this is far from the case, as universities exhibit a notable tendency to license to firms near them. While institutional commitments to promote local economic development explain some of this geographic clustering, it is also a byproduct of the importance of personal interactions and tacit knowledge in technology transfer.

In general, innovative entities tend to cluster around each other. From the nineteenth century, scholars have recognized the value of “agglomeration economies” wherein companies exploit spillovers arising from proximate firms in the same industry and region. More recent scholarship on the “new economic geography” has continued to explore industrial districts such as Silicon Valley, Route 128 near Boston, and the “Third Italy.”


213. The local nature of technology transfer manifests itself in other forms of decentralization as well. For example, while the ten-campus University of California system maintains a central TTO to handle high-level policy affairs, it maintains separate TTOs on individual campuses to handle local patenting and licensing functions.


Tacit knowledge plays an important role in accounting for geographic clustering.\textsuperscript{216} While traditional economic theory posits that information is capable of costless transmission,\textsuperscript{217} much information, particularly tacit information, is in fact quite “sticky.”\textsuperscript{218} Accordingly, technical problem solving requiring sticky information tends to take place near the source of that information.\textsuperscript{219} Such dynamics help explain why knowledge-intensive industries tend to be spatially concentrated: “By recombining and thereby augmenting fragmented, specialized, and mostly tacit knowledge, a multiplicity of cooperative firms in a cluster adapts rapidly to changes in the economic environment.”\textsuperscript{220} More precisely, the role of people as vehicles for transmitting tacit knowledge contributes significantly to geographical clustering because tacit knowledge transfer “requires frequent interaction that proximity facilitates.”\textsuperscript{221} Again, biotechnology offers an illustrative example, as the growth and diffusion of human capital largely drove the timing and geographic distribution of industrial developments in that field.\textsuperscript{222}

Technology-based firms cluster not only around each other, but also around universities.\textsuperscript{223} Firms may be particularly eager to locate near universities because academic institutions produce technical knowledge that is both highly valuable and openly available to the public.\textsuperscript{224} Universities welcome such agglomeration and have spearheaded a wide range of research parks, including the Stanford Industrial Park and the Research Triangle Park in North Carolina.\textsuperscript{225} Proximity to a university is most valuable for “early adopters” of innovation that derive competitive advantage from assimilating new knowledge.\textsuperscript{226} Tellingly, the tendency for companies to cluster around

\begin{thebibliography}{9}

\bibitem{216} See Gorga & Halberstam, suprano note 118, at 1146. Indeed, studies in innovation agglomeration arise at the intersection of tacit knowledge and localized knowledge spillovers. Agrawal, \textit{Knowledge Transfer}, suprano note 16, at 294; see also Bessen, Communicating Technical Knowledge, suprano note 33, at 33.


\bibitem{218} Von Hippel, suprano note 104, at 429, 432, 430 (characterizing tacitness as one component of the “stickiness” of information); Chon, suprano note 115; Zucker et al., \textit{Commercializing Knowledge}, suprano note 134, at 142.

\bibitem{219} Von Hippel, suprano note 104, at 429–30.

\bibitem{220} Gilson et al., suprano note 29, at 443; see also Audretsch & Feldman, suprano note 215, at 639.

\bibitem{221} Alcácer & Chung, suprano note 215, at 760; see Agrawal, \textit{Knowledge Transfer}, suprano note 16, at 294; Sturgeon, suprano note 215, at 219.

\bibitem{222} Zucker et al., \textit{Intellectual Human Capital}, suprano note 125, at 302.

\bibitem{223} See Feldman & Florida, suprano note 215, at 210 (”[t]he flow of information is increasingly dependent on a geographically defined infrastructure that is capable of mobilizing technical resources, knowledge, and other inputs essential to the innovation process.”).


\bibitem{225} Croissant & Smith-Doerr, suprano note 96, at 694.


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universities is more intense for “leader firms” with a high degree of absorptive capacity than for “laggard firms” that cannot readily assimilate academic knowledge.227

Empirical studies have confirmed the role of proximity in capturing university knowledge spillovers.228 Adam Jaffe and colleagues found that patent citations to university patents were statistically significantly more localized than citations to other sources.229 Analyses of state-level firm patent activity reveal the importance of geographically mediated spillovers from university research.230 Not surprisingly, firms are more likely to sponsor research at nearby universities rather than distant ones.231 Various studies have confirmed the impact of university research on the geographic distribution of firms in the electronics,232 drug and chemical,233 and biotechnology industries.234

Notably, geographic proximity is important even in the context of formal university patenting and licensing. While codified knowledge—such as that embodied in patents—is highly accessible, geography continues to influence its interpretation and assimilation.235 Surveying various studies, Ajay Agrawal concludes:

[D]espite the open-science culture that is prevalent in the university environment and that results in the regular publication and patenting of ideas that are equally available across all geographic space throughout most of the developed world, the commercialization of university inventions remains somewhat localized to the region of invention.236

In formal university-industry technology transfer, proximity matters.237

Of course, causality is difficult to determine, and it may be the case that intermediate variables explain geographic agglomeration. For example, the

227. Alcácer & Chung, supra note 215, at 773. In addition to seeking direct knowledge spillovers, firms also cluster around universities to access a highly educated labor pool of university graduates. Bania et al., supra note 215, at 762. This, too, reflects the exploitation of geographic proximity to capture university-generated knowledge.

228. See, e.g., Feldman & Florida, supra note 215, at 211, 225 (finding that university research and development is one of several key factors driving geographic clustering).

229. Jaffe et al., supra note 215, at 591.

230. Jaffe, supra note 224, at 967.

231. Mansfield, supra note 4, at 59. However, faculty quality is more important than geographic proximity as a determinant of sponsored research. Id.

232. Bania et al., supra note 215, at 765.

233. Jaffe, supra note 224, at 967.

234. Zucker et al., Commercializing Knowledge, supra note 134; Zucker & Darby, supra note 1, at 12,710.

235. Howells, Economic Geography, supra note 226, at 876; see also Lawson & Lorenz, supra note 215, at 311 (emphasizing the complementary nature of tacit and codified knowledge).

236. Agrawal, Knowledge Transfer, supra note 16, at 301.

237. Such is particularly the case for university start-ups, which tend to locate near the institutions that spawn them. Dante Di Gregorio & Scott Shane, Why Do Some Universities Generate More Start-Ups Than Others?, 32 RES. POL’Y 209, 210 (2003).
local availability of venture capital is widely believed to play a significant role in producing start-ups. It is possible that leading universities such as Stanford, Harvard, and MIT simply happen to be near venture capital firms, and it is the availability of such capital that encourages technology companies to cluster around them. That being the case, the majority of theoretical and empirical work suggests a more direct relationship between universities and the location of technology firms. As a descriptive matter, university technology transfer is localized to a much higher degree than what classic market-based conceptions would predict.

F. A Relationship-Oriented Conception of Technology Transfer

Empirical studies reveal that licensing markets are important but incomplete conduits for transferring patented university technologies to private firms. Licensing markets are far from robust, and TTOs and academic inventors must often exploit personal connections to find licensees. Once a licensee is onboard, technology transfer often unfolds as a complex process rather than a simple one-off conveyance of patent rights. In particular, licensees highly value tacit knowledge associated with patented inventions, and they seek to appropriate such knowledge through direct relationships with academic inventors. As a background consideration, firms cultivate absorptive capacity by maintaining ties to the academic community, thus setting the stage for appropriating new innovations. The relational, cognitively demanding nature of technology transfer helps account for several notable features of university licensing, such as its highly decentralized, local character.

In addition to the market, relationships emerge as valuable mechanisms of technology transfer. Surveys reveal that entrepreneurs, TTO administrators, and faculty scientists all place a high emphasis on personal relationships in technology transfer. In particular, direct relationships between inventors and

238. Zucker et al., Intellectual Human Capital, supra note 125, at 291.
240. Cf. Macneil, supra note 24, at 485 (“[D]iscrete exchange . . . can play only a very limited and specialized function in any economy, no matter how market-oriented that economy may be.”).
242. See Chon, supra note 115, at 180 (“The ‘sticky’ part of ‘sticky knowledge’ refers to the aspects of knowledge that have a stubbornly and sometimes irreducibly social dimension . . . .”); cf. Karl Polanyi, The Economy as an Instituted Process, in TRADE AND MARKET IN THE EARLY EMPIRES: ECONOMIES IN HISTORY AND THEORY 243 (Karl Polanyi et al. eds., 1957) (noting that market relationships are embedded in both economic and noneconomic institutions); Macneil, supra note 24, at 490.
243. Siegel et al., Effective Transfer, supra note 5, at 131 (finding that 75 percent of entrepreneurs, 67 percent of TTO administrators, and 80 percent of university scientists considered personal relationships important in technology transfer); cf. Macaulay, Non-contractual Relations,
licensees are often critical to successful commercialization. Such relationships allow inventors to convey tacit information that is difficult to codify and/or uniquely tailored to a licensee’s particular needs. Scientists and firms understand that relationship building is critical to informal knowledge dissemination, and most parties in technology transfer regard personal relationships as more important than contractual relationships.

In light of the need to convey tacit knowledge in order to achieve commercialization, relationships may develop into deeper organizational connections among transacting entities. As we will see, these connections may even begin to resemble traditional forms of organizational integration. The next Part provides a theoretical framework for understanding organizational innovations developed by universities, scientists, and firms to transcend the limitations of formal patent licensing and enhance tacit knowledge transmission. To do so, it delves deeper into an underutilized resource for understanding university-industry technology transfer: the theory of the firm.

III.
ORGANIZATIONS: TRANSACTIONAL HAZARDS, PATENTS, AND ORGANIZATIONAL INTEGRATION

While formal technology transfer is often equated with patenting and licensing of university inventions, such activities do not transfer tacit technical knowledge that is highly valuable to licensees. The limitations of patents and licenses, moreover, encourage deeper, more tactile relationships between academic patentees and licensees. Drawing from the theory of the firm, this Part argues that the objective of conveying tacit information may motivate even

supra note 24 (examining the importance of personal relationships alongside formal contracts in business deals).

244. Jensen & Thursby, supra note 6, at 241; Thursby & Thursby, Are Faculty Critical?, supra note 102, at 168.

245. Link et al., supra note 241, at 645 (“Human capital is often associated with tacit knowledge, and tacit knowledge engenders scientists to firms.”).


247. Siegel et al., Effective Transfer, supra note 5, at 132; Siegel et al., Assessing the Impact, supra note 106, at 41; Nicol, supra note 246, at 231; see Link et al., supra note 241, at 644–45 (noting that social networks help drive technology transfer); Chon, supra note 115, at 192 (“In short, people and their relationships—including their quirks and their ability to connect, as well as their possible disconnects—are critical for knowledge diffusion.”); cf. Macaulay, Non-contractual Relations, supra note 24, at 58. Notably, the Bayh-Dole Act, which is generally associated with contract-based technology transfer, also aimed to promote collaboration between universities and commercial firms. 35 U.S.C. § 200 (2006). Furthermore, academic scientists sometimes bypass formal patenting and licensing altogether, resorting to informal technology transfer based on social and personal connections alone. See, e.g., Nicol, supra note 246, at 208.
stronger linkages between licensor and licensee entities, culminating in vertical integration. This Part explores, at a general level, the theory of the firm and the relationship of transaction costs and tacit knowledge to organizational structure; the next Part applies these findings to the specific context of university-industry technology transfer.

A. The Theory of the Firm

As Ronald Coase explored in his seminal article *The Nature of the Firm*, firms face a “make or buy” decision regarding the acquisition of inputs to production. On the one hand, the availability of price-based market transactions suggests that enterprises should simply “buy” such inputs on the market, essentially outsourcing upstream production functions to independent suppliers. On the other hand, the significant degree of vertical integration throughout the economy suggests that in certain circumstances, “making” inputs within a vertically integrated firm is preferable to buying them on the market. Such vertical integration may arise through developing upstream production functions in-house or by buying an upstream supplier and integrating it into the firm.

Coase’s central insight is that lower transaction costs explain the existence of integrated firms. Organizing production via voluntary contracts in the market exhibits many efficiencies, but it also introduces costs. “Hierarchical” production in a firm eliminates many transaction costs of market-based exchanges (through it may introduce new ones) by reducing the friction, expense, and potential opportunities for exploitation arising from price-based exchange. Put simply, it may cost less to organize production internally within a hierarchical firm than to negotiate prices and write contracts in the market.

Subsequent commentators have extended Coase’s insights on the relationship between transaction costs and vertical integration. In particular, they have enumerated various “transactional hazards” that render contracting with a separate firm more costly than simply vertically integrating with it. Scholars of transaction-cost economics have especially focused on opportunistic behavior where one party can “hold up” a transaction when the other party has made asset-specific investments dependent on the transaction’s completion. For instance, a buyer may take advantage of a supplier who has...
invested considerably in producing a specialized input that is only valuable to that particular buyer.253 Strategic behavior, however, is not the only transaction cost that complicates contracting. Parties face a host of additional hazards, including those arising from weak property rights (including intellectual property rights), measurement difficulties, and weak enforcement.254

Put more broadly, agreements between sellers and buyers may be plagued by the “incompleteness” of contracts.255 It may be impossible or prohibitively expensive for parties to write contracts that anticipate all contingencies and allocate precisely any surplus arising from a deal.256 The “incompleteness” of contracts, moreover, raises transaction costs, thus rendering “buying” inputs on the market less attractive than simply vertically integrating and “making” them in-house.257 Expositors of the property rights theory of the firm note that “[w]hen it is too costly for one party to specify a long list of the particular rights it desires over another party’s assets, it may be optimal for that party to purchase all the rights except those specifically mentioned in the contract.”258 Purchase of these “residual” control rights is tantamount to ownership of the party itself259 or vertical integration.260 In short, the difficulties of contracting with another party counsel in favor of simply integrating with it.261

Burk & McDonnell, supra note 53, at 580; Oxley, supra note 120, at 387; Gilson et al., supra note 29, at 495.


260. This discussion blends two related lines of scholarship: Williamson’s transaction-cost economics (TCE) and Grossman, Hart, and Moore’s (GHM) property rights theory of the firm. While both of these approaches address the make-or-buy decision arising from incomplete contracts, they exhibit certain technical differences. See, e.g., Gorga & Halberstam, supra note 118, at 1136–37 (critiquing the property rights theory of the firm as focusing on physical as opposed to human capital); Williamson, New Institutional Economics, supra note 25, at 605–07 (describing differences between the TCE and GHM frameworks).

261. See Gilson et al., supra note 29, at 437 (“Vertical integration was a response to the threat of production-process disruption.”).
B. Patents and Technology Transactions

The role of transaction costs and property rights in determining organizational forms is particularly relevant to technology transactions. Of course, technology transactions are prone to all of the traditional hazards that afflict contracts in general. In addition, technologies are notoriously difficult to value, further complicating transactions. Furthermore, the difficulties of writing contracts to specify all the elements of a desired invention can seriously complicate technology supply agreements.262

Additionally, “Arrow’s information paradox” creates a unique kind of transaction cost.263 As Kenneth Arrow noted, a seller of some technology will be reluctant to disclose it to a prospective buyer out of fear that the buyer will appropriate it for free. However, unless the buyer can inspect the technology before buying it, she is unlikely to purchase it. This threat of expropriation significantly imperils technology transactions, thus counseling in favor of vertical integration rather than market-based contracting.264

Significantly, patents play a valuable role in mitigating several hazards affecting technology transactions. Patents overcome Arrow’s information paradox by establishing “precontractual liability” for unauthorized exploitation of technical information.265 With a patent, a technology producer can “market” her invention freely, secure in the knowledge that any unauthorized use by third parties will give rise to infringement liability. Furthermore, as opposed to purely contractual rights and obligations, patents provide technology suppliers with additional remedies in case of unauthorized exploitation of an invention.266 Patents promote technology transactions in other ways as well. For instance, they facilitate “affirmative asset partitioning” by shielding firm assets from the creditors of the owners or managers of that firm.267 Additionally, patents reduce the need to “fence off” information from parties within an organization, thus facilitating team production of information assets.268 Finally, as publicly recorded instruments, patents provide “a focal point, or beacon” that allows technology buyers and sellers to find each other relatively easily in the marketplace.269 In all of these respects, patents facilitate

262. Cf. Aghion & Tirole, supra note 28, at 1189 (presenting a model of technology transactions assuming that research contracts are inherently incomplete).
263. See Arrow, Economic Welfare, supra note 217, at 614–16.
264. See Barnett, Organization, supra note 131, at 810.
265. Merges, Transactional View, supra note 77, at 1502–04; see Shane, Selling University Technology, supra note 64, at 124; Scott Shane, Encouraging University Entrepreneurship? The Effect of the Bayh-Dole Act on University Patenting in the United States, 19 J. BUS. VENTURING 127, 131 (2004) [hereinafter Shane, Encouraging University Entrepreneurship?].
268. Id. at 487.
269. Kieff, supra note 99, at 735; see Kitch, supra note 51, at 278–89.
technology transactions between separate firms, thus rendering “buying” intermediate goods potentially more attractive than “making” them in-house.270

Even where patents mitigate “standard” contracting hazards, however, the difficulty of conveying patent-related tacit knowledge represents a unique and potentially significant transaction cost.271 Turning Arrow’s information paradox on its head, difficulties arise in this context not from the seller’s concern that the buyer can easily appropriate technical information without authorization (since by definition, tacit knowledge is very difficult to appropriate). Rather, transactional hazards arise from the inability of parties to negotiate over and convey tacit knowledge in a direct, low-cost manner.272

Notably, patents can also alleviate costs related to conveying tacit knowledge. To begin, patents require the codification of tacit (or, more precisely, latent) knowledge, thus facilitating its low-cost dissemination.273 As noted above, however, even when a patent satisfies the disclosure requirements of 35 U.S.C. § 112, much valuable knowledge remains tacit.274 That being the case, when patents and tacit knowledge are highly complementary, licensors can sometimes package them together.275 In this vein, patents can facilitate side agreements and consulting engagements between licensors and licensees to help transfer tacit knowledge.276 Thus, “tacitness of know-how creates problems of contractibility, but complementarity between know-how and other inputs can overcome this problem.”277 Accordingly, sophisticated patentees often seek to license invention-related tacit knowledge along with the patent itself.278 As a result, patents represent the “leading wedge” that initiates greater linkages (and technical communication) between licensor and licensee.279

271. See Gilson et al., supra note 29, at 496–97.
272. See Oxley, supra note 120, at 394.
273. Burk, Knowledge Codification, supra note 63, at 1012.
274. See supra Part II.B.
277. Arora, Contracting for Tacit Knowledge, supra note 118, at 244.
278. Burk, Knowledge Codification, supra note 63, at 1021; see also Merges, Transactional View, supra note 77, at 1501.
279. Arora, Contracting for Tacit Knowledge, supra note 118; Merges, Transactional View, supra note 77, at 1500–02. Thus, patents can increase the rate of transfer of unprotected trade secrets and know-how. Arora, Licensing Tacit Knowledge, supra note 76, at 42. Along these lines, Ashish Arora argues that stronger intellectual property rights also facilitate the increased efficiency of licensing contracts for transferring tacit knowledge. Arora, Contracting for Tacit Knowledge, supra note 118, at 234. Indeed, a transparent and well-articulated intellectual property rights regime is critical to flows of both codified and tacit knowledge. See, e.g., Debackere & Veugelers, supra note 206, at 324.
C. Specialized Knowledge Inputs and Organizational Integration

Ultimately, however, the ability of patents to convey technical knowledge—either directly or by bundling licenses with service contracts—may reach a limit. Commentators thus note that “[t]he highly uncertain and non-codifiable nature of scientific know-how results in high transaction costs and in systemic failures in the market for this know-how . . . .” 280 In light of market failure, organizational integration emerges as a viable option for conveying tacit knowledge, even in the presence of patents. 281 Such integration emerges not to address “classic” strategic behavior but to ameliorate the difficulties of conveying technical information between separate organizations. In this context, I use the term “integration” in a broad sense to connote not only formal vertical integration, but also more subtle organizational interpenetrations. A continuum thus emerges in which the enhanced efficiencies of conveying tacit knowledge within a common organizational context—as opposed to between two separate entities—often motivates varying degrees of integration. 282

At one end of the spectrum, knowledge-transfer efficiencies may lead to outright vertical integration. One sees this phenomenon, for example, in certain developments in the biotechnology industry in the 1980s and 1990s. 283 Historically, this industry was characterized by a division of labor in which specialized biotechnology firms performed cutting-edge research while established pharmaceutical firms conducted large-scale clinical trials, manufacturing, and marketing. 284 Biotechnology firms and pharmaceutical companies frequently utilized contracts, joint ventures, and other agreements to collaboratively develop new drugs and diagnostics. During the 1980s and early 1990s, however, many biotechnology firms began “integrating forward” into wide-scale manufacturing and marketing of biotechnology products. 285 Additionally, some large, established pharmaceutical companies began “integrating backward” to conduct upstream research. 286 This was often accomplished through a pharmaceutical company buying (and thus vertically

280. Debackere & Veugelers, supra note 206, at 324.
281. See Oxley, supra note 120, at 388 (noting that the logic of transaction costs favors more hierarchical alliances where contracting hazards are more severe).
282. Cf. KENNETH J. ARROW, THE LIMITS OF ORGANIZATION (1974) (noting that one of the advantages of firms is low costs of information transmission within the organization).
283. Powell, supra note 203, at 206 (“Even fully committed partners [in biotechnology] may find it difficult to transfer complex, tacit technological know-how across organizational boundaries.”); see Kogut & Zander, supra note 126, at 389 (“[A] fundamental problem arises in the shifting of technologies from research groups to manufacturing and marketing.”).
284. See Owen-Smith & Powell, supra note 105, at 607.
285. Pisano, Governance of Innovation, supra note 164, at 238.
286. Id. at 243.
integrating with) a biotechnology company, such as when Schering-Plough purchased DNAX in 1982.\textsuperscript{287}

Efficiencies in exploiting tacit knowledge within a single organization helped motivate such integration.\textsuperscript{288} For example, scientists who genetically engineer cells develop knowledge that greatly facilitates the scaling-up of protein production; to exploit this tacit knowledge, biotechnology firms that conduct genetic engineering began performing this latter function in-house.\textsuperscript{289} Similarly, the difficulties of capturing upstream, tacit research findings in outside research contracts helped motivate pharmaceutical firms to conduct such research in-house.\textsuperscript{290}

Abstracting away from outright vertical integration, knowledge demands may motivate more intermediate forms of integration.\textsuperscript{291} For example, the need to share technical—often tacit—knowledge often leads formally separate firms to engage in joint ventures, collaborations, or project-specific partnerships.\textsuperscript{292} As a general phenomenon, joint ventures often arise in technology-oriented industries to facilitate tacit knowledge transfer between firms.\textsuperscript{293} Additionally, in industries using standardized interfaces, “iterative collaboration” between platform and application developers facilitates mutual observation and learning that help communicate tacit knowledge.\textsuperscript{294}

\textsuperscript{287.} See Martin Kenney, Biotechnology: The University-Industrial Complex 202 (1986).

\textsuperscript{288.} Pisano, Governance of Innovation, supra note 164, at 244.

\textsuperscript{289.} Id. at 244.

\textsuperscript{290.} Id. at 247.

\textsuperscript{291.} Alfred Chandler famously chronicled the rise of large integrated firms that have long dominated American business history. Alfred D. Chandler Jr., The Visible Hand: The Managerial Revolution in American Business (1977). However, more recent scholars have argued that industrial organization has entered a “post-Chandlerian” phase characterized by small disintegrated firms that coordinate production through market exchanges. See, e.g., Arora & Merges, supra note 275, at 454; Richard N. Langlois, The Vanishing Hand: The Changing Dynamics of Industrial Capitalism, 12 Indus. & Corp. Change 351, 352–53 (2003). Notwithstanding this trend, the persistence of organizational ties between upstream and downstream entities reveals the continuing importance of integration across supply chains. Such integration is particularly useful in high-tech industries as a conduit for transferring technical knowledge.

\textsuperscript{292.} Powell et al., supra note 246, at 117 (1996) (“[T]he decision to collaborate is a variant of the make-or-buy decision, framed largely in terms of transaction cost[s].”); see Kogut & Zander, supra note 126, at 395 (“[j]oint ventures . . . provide a vehicle by which firms transfer and combine their organizationally-embedded learning.”); Naomi R. Lamoreaux et al., Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History, 108 Am. Hist. Rev. 404, 426 (2003); Oxley, supra note 120, at 393–94 (noting the advantages of hierarchical organization in reducing technology transfer costs).

\textsuperscript{293.} Bruce Kogut, Joint Ventures, Theoretical and Empirical Perspectives, 9 Strategic Mgmt. J. 319, 323 (1988); see also Pisano, Governance of Innovation, supra note 164, at 237 (“[i]n many contemporary industries, joint ventures and other forms of inter-firm cooperation are playing an increasingly important role in the development, commercialization, and diffusion of technical know-how.”).

\textsuperscript{294.} Gilson et al., supra note 29, at 447, 475; see also Edwards, supra note 32, at 1227–28 (chronicling the rise of several biotech business models predicated on intensive partnerships with pharmaceutical firms); Langlois, supra note 291, at 376; Charles F. Sabel & Jonathan Zeitlin, Neither
Abstracting even further, knowledge demands may motivate looser, more flexible organizational ties best captured by the concept of networks.\textsuperscript{295} Networks are important for providing access to the background knowledge necessary to exploit new innovations. They are particularly helpful in cutting-edge fields where aggregating and synthesizing broadly distributed knowledge confers a competitive advantage.\textsuperscript{296} As sociologist Walter Powell and colleagues observe, collaborative networks represent a crucial conduit for sharing knowledge among players in the biotechnology industry.\textsuperscript{297} Tellingly, Powell characterizes this “macro-level mutualism” as “virtual integration.”\textsuperscript{298}

Various degrees of organizational integration thus emerge as important conduits for tacit knowledge transmission. In classic articulations of the theory of the firm, vertical integration mitigates transaction costs of market-based production, including the threat of opportunistic behavior by one or both contracting parties.\textsuperscript{299} In the realm of technology transactions, patents can reduce such costs, thus enhancing the viability of contracting between independent parties. However, patents cannot fully transfer tacit knowledge that is highly valuable for exploiting new innovations. Thus, independent of opportunistic threats, the difficulties of transferring tacit knowledge can motivate vertical integration. From bringing needed technical expertise in-house to forming joint ventures to exploiting networks, various degrees of organizational integration serve to transmit technical knowledge. The value of such organizational meshing to tacit knowledge transmission, moreover, raises the question of whether these organizational forms also apply to university-industry technology transfer.

IV. UNIVERSITY-FIRM INTEGRATION AND TACIT KNOWLEDGE TRANSFER

As we have seen, the predominant market-based conception of formal technology transfer presumes that exchanging patent rights is sufficient to

\textit{Modularity nor Relational Contracting: Inter-firm Collaboration in the New Economy}, 5� \textit{Enterprise & Soc’y} 388, 397 (2004). Notably, the modularization of the "post-Chandlerian" economy is enabled by standardized interfaces and production specifications between various firms along a supply chain. Langlois, supra; see Barnett, \textit{Organization}, supra note 131, at 820, 844 n.128. However, it is precisely the difficulty of standardizing an "interface" when transferring a new technology that helps explain the significant degree of integration in high-tech industries. See Sabel & Zeitlin, supra, at 391.


\textsuperscript{296} Powell et al., \textit{supra} note 246, at 119 ("[W]hen knowledge is broadly distributed and brings a competitive advantage, the locus of innovation is found in a network of interorganizational relationships.").

\textsuperscript{297} See Powell, \textit{supra} note 93, at 208; Powell et al., \textit{supra} note 246, at 138–39 ("[N]etworks of collaboration provide entry to a field in which the relevant knowledge is widely distributed and not easily produced inside the boundaries of a firm or obtained through market transactions.").

\textsuperscript{298} Powell, \textit{supra} note 93, at 209.

\textsuperscript{299} See, \textit{e.g.}, Klein et al., \textit{supra} note 28.
transfer a technology. However, empirical studies of university-industry licensing indicate otherwise. Relationships among universities, academic inventors, and private licensees are critical to transferring the tacit knowledge that is essential to exploiting patented academic inventions. The theory of the firm and related insights predict that the need to transfer tacit knowledge can motivate more intensive forms of organizational integration—from collaborative networks to outright consolidation. This Part adapts the theory of the firm to present a descriptive theory of formal university-industry technology transfer. It argues that even in the presence of patents and licenses, varying degrees of organizational integration play a valuable role in transferring tacit knowledge, and ultimately, academic inventions to the private sector.

Applying the theory of the firm to university-industry technology transfer, a company in a research-intensive industry faces a “make or buy” decision regarding obtaining early-stage technological inputs. On the one hand, it could “buy” an early-stage technology by licensing a university patent. However, because of the insufficiency of one-off contracts and the inadequacy of patent disclosure, a license may not transfer the tacit knowledge necessary to exploit this invention optimally. This raises the possibility of the company integrating with a university, thus developing the technological prospect (and exploiting tacit knowledge) in-house. While one doesn’t normally consider this to be possible—imagine Merck merging with the UC Davis Department of Molecular and Cellular Biology—this Part contends that to varying degrees, such integration is already occurring.

This Part argues that university-industry technology transfer—even in the context of formal patent licensing—is often characterized by organizational “integration” that facilitates tacit knowledge transfer. University-industry

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300. See Agrawal, Technology Acquisition Strategy, supra note 144, at 2.
301. Lowe, supra note 148, at 415; Dasgupta & David, supra note 114, at 517.
302. Recent scholarship reveals a high degree of disintegration in contemporary industrial organization: whereas in the past, large integrated firms performed R&D in-house, these days, firms are more commonly buying inputs from independent suppliers. Ronald J. Gilson et al., Contracting for Innovation: Vertical Disintegration and Interfirm Collaboration, 109 COLUM. L. REV. 431, 434 (2009). I argue, on the contrary, that university-industry relations are becoming more vertically integrated. While these theses appear to be in tension, the conflict largely arises from different frames of reference. Gilson et al. start from “[c]onventional industrial organization theory,” which predicts significant vertical integration in rapidly innovating industries. Id. at 433. Within this frame of reference, more contract-like organization suggests a greater degree of vertical disintegration than what theory would predict. I start with the conventional proposition that universities and licensee firms are discrete entities that engage in arm’s-length contracting. Within this frame of reference, increasing organizational ties reflect greater vertical integration than would normally be expected. Importantly, both of our theses lead to similar conclusions: innovative activity—including that which spans universities and commercial firms—relies on fluid organizational structures lying somewhere between the poles of pure hierarchical and market production.
303. Shane, Encouraging University Entrepreneurship?, supra note 265, at 131 (noting that when information transmission costs are sufficiently high, due in part to the difficulties of conveying tacit knowledge, transferring knowledge outside of an organization becomes too expensive to be
integration can take a variety of forms, from firms sponsoring academic research or hiring faculty inventors as consultants to “true” consolidation of academic and entrepreneurial functions in university start-ups. Because these types of integration differ from the more formal kinds of integration associated with the classic theory of the firm, it is important to acknowledge the broad sense in which this Article uses the term “integration.” Many of these activities do not constitute “vertical integration” in the strict antitrust sense. For instance, Merck has not yet purchased the UC Davis Department of Molecular and Cellular Biology. Additionally, “integration” may entail layering one set of contractual relationships (such as a consulting agreement with an academic inventor) on top of another (such as a license with a TTO) rather than “true” consolidation of upstream and downstream functions.

Instead, integration as it is used here refers to the blurring of organizational boundaries to allow firms to more efficiently absorb academic human capital. Among other implications, integration challenges the conventional boundaries of the institutions involved in university-industry technology transfer. “Universities” and “licensee firms” emerge not as hard-edged, discrete entities, but as nodes in a fluid network of relationships.

A. Sponsored Research

Commercial sponsorship of university research represents an important conduit for transferring tacit knowledge and accelerating university-industry technology transfer. Such sponsorship exposes firms to the latest academic

worthwhile); Oxley, supra note 120, at 392 (describing appropriability hazards, which include the difficulty of obtaining tacit knowledge). This Part presents a descriptive theory of university-industry integration, leaving normative evaluations for Part V.


305. See Shane, Selling University Technology, supra note 64, at 127 (arguing that arrangements lacking equity ownership, such as mere scientific board membership and consulting, do not reflect vertical integration in the strict sense).

306. But see Zucker et al., Commercializing Knowledge, supra note 134, at 151 (describing instances where academic scientists are “being ‘vertically integrated’ into the firm in the sense of receiving equity compensation and being bound by exclusivity agreements”); Howells, Technology Transfer, supra note 117, at 102 (describing tacit knowledge flows that “relate most directly to encouraging know-how sharing with firms that are vertically related to the sharing or providing firm”).

307. However, at least one commentator suggests that BP has purchased a part of UC Berkeley. See Jennifer Washburn, Big Oil Buys Berkeley: The BP-UC Berkeley Research Deal Pushes Academic Integrity Aside for Profit, L.A. TIMES, Mar. 24, 2007, at A21.

308. See Murray, Laboratory Life, supra note 138, at 652; see also Howells, Technology Transfer, supra note 117, at 95; cf. Gorga & Halberstam, supra note 118, at 1145 (“The non-communicable character of tacit knowledge suggests it is best obtained by integrating individuals who possess it into a firm’s production process as employees, rather than seeking to acquire such knowledge inputs through market transactions.”).
science, thus enhancing their absorptive capacity. More broadly, sponsorship commonly entails joint research between academic and industrial scientists, which is a key mechanism for exchanging tacit knowledge.

Importantly, sponsored research frequently involves significant organizational integration between universities and firms. In some instances, sponsoring firms implant scientists in academic laboratories. Sponsorship may even blur the lines as to whether research faculty work for a university or the sponsor. Additionally, “hybrid” institutions may emerge to mediate sponsored research at universities. For example, the Whitehead Institute for Biomedical Research at MIT reflects “an attempt to create an inter-penetrating system of public and private research within a university setting.”

Sponsored research often produces patented inventions, and the “inside knowledge” of sponsors is helpful both in identifying licensing opportunities and in appropriating new discoveries. In some instances, strategically located industry personnel become aware of commercially promising academic projects even before a university begins to market them. Oftentimes, as with the arrangement between Harvard Medical School and Monsanto, firms obtain the exclusive rights to license any discoveries resulting from sponsored research. Along these lines, UC Irvine has pioneered an approach whereby firms sponsor research in specific areas in exchange for exclusive licenses to any resulting patented inventions as well as rights to sponsor research in related areas. Firms routinely use sponsored research to maintain relationships with faculty inventors whose inventions they are licensing or seek to license.

In a recursive fashion, many university licenses require commercial licensees to sponsor additional research. According to one survey, roughly a third of university licenses involved some sort of sponsored research funded by

309. See supra Part II.C.
311. Murray, Laboratory Life, supra note 138, at 654.
312. Argyres & Liebeskind, supra note 3, at 440 (describing Hoechst’s funding of research at Massachusetts General Hospital). Of course, such arrangements have attracted significant criticism. See infra Part V.C.
315. See Kenney, supra note 287, at 58; id. at 63, 64, 65, 68 (noting similar provisions in agreements between MGH and Hoechst, Harvard Medical School and Du Pont, UC Davis and Allied, and Washington University and Monsanto).
316. Argyres & Liebeskind, supra note 3, at 444.
317. Thursby & Thursby, Are Faculty Critical?, supra note 102, at 175.
the licensee firm. In another survey, 11 percent of TTOs used licensing for sponsored research as their predominant licensing strategy. In this vein, sponsored research helps maintain an ongoing relationship between licensor and licensee, thereby facilitating even more tacit knowledge transmission. Sponsored research is thus both a conduit by which firms obtain tacit knowledge related to academic inventions and a driving force behind generating new innovations.

B. Directly Engaging Academic Inventors in Commercialization Efforts

Firms’ interest in engaging academic inventors (and their tacit knowledge) often intensifies in the context of established licensing agreements. After all, directly interacting with faculty inventors may greatly accelerate appropriating and exploiting a new technology. In one survey, university licensees attributed 18 percent of commercialization failures to ineffectiveness or noninvolvement of faculty members associated with the licensed technology. In a series of case studies, seven of eleven instances of technology transfer involved ongoing interaction between the faculty inventor and the licensee during commercialization. Furthermore, analyses of licenses based on inventions developed in the Mechanical Engineering as well as Electrical Engineering and Computer Science departments at MIT revealed that engaging the academic inventor positively impacted the likelihood of commercialization and increased royalties.

In many instances, firms licensing a university patent will hire the academic inventor as a consultant. In general, consulting relationships involving academic faculty have become quite common. Of course, academics consult for firms for a host of reasons, including those unrelated to exploitation of any patent. However, in the technology transfer context, surveys indicate that consulting is the most frequently utilized mechanism for transferring inventor knowledge to a licensee firm. While consultants remain

318. Jensen & Thursby, supra note 6, at 246.
320. See Link et al., supra note 241, at 642.
321. See supra Part II.B.
322. Thursby & Thursby, Are Faculty Critical?, supra note 102, at 167.
323. Colyvas et al., How Do University Inventions Get into Practice?, supra note 104, at 64.
324. Agrawal, Engaging the Inventor, supra note 122, at 20–21.
325. See KENNEY, supra note 287, at 104.
326. Karen Seashore Louis et al., Entrepreneurs in Academe: An Exploration of Behaviors Among Life Scientists, 34 ADMIN. SCI. Q. 110, 113 (1989); see also KENNEY, supra note 287, at 91–93; Mansfield, supra note 4, at 64.
327. Thursby & Thursby, Are Faculty Critical?, supra note 102, at 170; Argyres & Liebeskind, supra note 3, at 450; see Thomas Hellmann, The Role of Patents for Bridging the Science
independent contractors—not employees—such engagements represent an attempt to absorb inventor knowledge and expertise directly into a licensee firm.

More ambitiously, academic inventors often serve as more permanent technical advisers and may even join the boards of directors for licensee companies, particularly start-ups. The origins of the biotechnology industry, where the links between academic inventors and private firms have been particularly pronounced, help illustrate this phenomenon. Herbert Boyer of the University of California, San Francisco (UCSF) and Stanley Cohen of Stanford invented and patented the foundational techniques of recombinant DNA technology that undergird modern genetic engineering. Cetus and Genentech were among dozens of biotechnology companies that licensed this technology. Around the time of licensing, Cohen served as a scientific adviser to Cetus, and Boyer was a member of Genentech’s board of directors. While Cohen and Boyer’s positions likely served a number of strategic objectives, their placements also facilitated the transfer of tacit knowledge related to their patented inventions.

Indeed, the success of the biotech industry as a whole owes much to the early involvement of academic scientists in commercial development. Star bioscientists centrally determined when and where new biotechnology enterprises began to use biotechnology commercially and which ones were most successful. Local academic stars had significant positive effects on the number of products in development and released to market as well as on employment growth. Indeed, IPO prospectuses for early biotech firms frequently highlighted the participation of star scientists.

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to Market Gap, 63 J. ECON. BEHAV. & ORG. 624, 627 (2007); see also Howells, Technology Transfer, supra note 117, at 95.

328. Siegel et al., Effective Transfer, supra note 5, at 118; see Kenney, supra note 287, at 149–54 (describing Scientific Advisory Boards in the biotechnology industry).


330. Kenney, supra note 287, at 90 (“The advent of genetic engineering has led many companies to return to school.”).

331. Lewin, supra note 239; see Sally Smith Hughes, Making Dollars out of DNA: The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974–1980, 92 Isis 541, 562 (2001) (“What raised concern in Cohen’s case was the fact that he was an inventor on a Stanford patent application and at the same time a paid consultant for a company seeking a license on the invention being patented.”). In fact, Boyer had cofounded Genentech. Kenney, supra note 287, at 94 (“Genentech was presumably started on Boyer’s consulting time while he was a professor at the UCSF Medical Center.”).


333. Zucker & Darby, supra note 1, at 12,710. The authors define “star scientists” as those having more than forty genetic sequence discoveries or twenty or more articles reporting genetic sequences by 1990. Cf. Murray, Innovation as Co-evolution, supra note 304, at 1401 n.23 (noting that early scientists were closely engaged in both the scientific and technical communities in developing recombinant DNA technology).

334. Zucker & Darby, supra note 1, at 12,712.

335. Zucker et al., Commercializing Knowledge, supra note 134, at 143.
biotechnology firms in 1994 reported at least one “star” academic scientist on their team when going public; seven of them had linked articles (a star scientist copublishing with a firm employee).336 Of course, involving star scientists also served other functions, such as signaling technical expertise to capital markets and providing access to a scientist’s network of collaborators.337 Notwithstanding these functions, however, the importance of knowledge exchange loomed large, as “university-firm technology transfer for breakthrough discoveries generally involves detectable joint research between top professors and firms that they own or are compensated by.”338 While the close link between academic inventors and commercializing firms is best documented in biotechnology, it extends to other fields as well, such as semiconductors.339 Case histories and scholarly accounts suggest more generally that directly engaging academic intellectual human capital plays an important role in commercializing university discoveries.340

C. Consolidation of Academic and Entrepreneurial Functions in University Start-Ups

Engaging faculty inventors is particularly important to start-ups that license university patents. Approximately 12 percent of university-owned inventions are transferred to the private sector by establishing start-ups,341 and universities’ support for such arrangements is rising.342 Where the academic inventor is not the principal entrepreneur, the inventor’s ongoing participation in commercialization efforts is often critical to success.343 However, in many cases, upstream academic and downstream entrepreneurial functions are completely integrated when a faculty inventor establishes a new firm.344 As noted above, empirical studies confirm that star scientists were often deeply involved in forming new biotechnology firms.345 Commentators have suggested that because much scientific knowledge is tacit, university scientists must become entrepreneurs to exploit it commercially.346

336. Id. at 144.
337. Murray, Laboratory Life, supra note 138, at 645; Geljins & Thier, supra note 17, at 73.
338. Zucker et al., Commercializing Knowledge, supra note 134, at 149; see Zucker et al., Intellectual Human Capital, supra note 125; Zucker & Darby, supra note 1, at 12,709.
339. Zucker & Darby, supra note 1, at 12,715; supra Part II.B.1.
340. Zucker & Darby, supra note 1, at 12,715.
341. Di Gregorio & Shane, supra note 237, at 209.
344. Cf. id. at 186, 196.
345. Zucker & Darby, supra note 1, at 12,713 n.k; Powell, supra note 203, at 200. According to one observer, “[t]he pervasive role of professors in managing and directing [biotechnology] startups is unique in the annals of business history.” Kenney, supra note 287, at 4; see id. at 94 (“All of the earliest genetic engineering companies were founded by professors.”); id. at 98 (listing the involvement of founding professors with various companies).
346. Di Gregorio & Shane, supra note 237, at 212; see Lowe, supra note 148, at 420. Start-ups, however, may face challenges when a commercially inexperienced scientist focuses too much on
The example of SynapSense, discussed above, provides an illustrative case study.\textsuperscript{347} As noted, SynapSense is a “cleantech” start-up organized around intellectual property licensed from UC Davis. The inventor of this intellectual property is Dr. Raju Pandey, a UC Davis computer science professor who is also a SynapSense cofounder. Currently, Dr. Pandey remains on the UC Davis faculty but also serves as SynapSense’s Chief Technology Officer. While Dr. Pandey plays a variety of roles at SynapSense, his day-to-day involvement with the company greatly facilitates the exploitation of tacit knowledge related to university intellectual property.

\textbf{D. Institutional Linkages}

While the foregoing examples involve linking individual academic inventors with commercial firms, higher-level integration between organizations may also facilitate technology transfer.\textsuperscript{348} To this end, universities are building institutions to further integrate academic and commercial functions. For example, many universities are creating “incubators” to promote commercialization of academic technologies.\textsuperscript{349} Some of these initiatives take the form of “proof of concept centers,” which are involved in technology commercialization much earlier than traditional business incubators.\textsuperscript{350} A primary objective of such incubators is to facilitate close working relationships between university inventors and entrepreneurs to aid in commercialization.\textsuperscript{351}

\textsuperscript{347} See supra notes 9–10 and accompanying text.

\textsuperscript{348} Empirical studies of Air Force laboratories reveal the importance of institutional ties to effectively transfer military technology to civilian users. Michael A. Greiner & Richard M. Franz, \textit{Barriers and Bridges for Successful Environmental Technology Transfer}, 28 J. TECH. TRANSFER 167 (2003). In one case study involving the development of a maintenance-free aircraft battery, the technology-transferring organization found that communication devices such as newsletters, meetings, and training sessions, as well as strong laboratory-user relationships, were critical to success. \textit{Id.} at 171. In case studies involving a halon replacement system, rapid optical screening tool, and bioventing process, survey respondents at government laboratories cited the establishment of a technology transfer “champion” at the receiving firm as the most important factor contributing to successful transfer. \textit{Id.} at 171–72; S.J. Guilfoos, \textit{Bashing the Technology Insertion Barriers}, 13 AIR FORCE J. LOGISTICS 27 (1989).

\textsuperscript{349} See Gelijns & Thier, supra note 17, at 75; Markman et al., supra note 319, 244–45 (describing the Rensselaer Polytechnic Institute incubator); \textit{id.} at 252 (reporting survey results that 62 percent of TTO respondents devoted significant resources to building business incubators); Bob Tedeschi, \textit{The Idea Incubator Goes to Campus}, N.Y. TIMES, June 27, 2010, at BU1.

\textsuperscript{350} Tedeschi, supra note 349; see EWING MARION KAUFFMAN FOUND., PROOF OF CONCEPT CENTERS: ACCELERATING THE COMMERCIALIZATION OF UNIVERSITY INNOVATION (2008) (describing the Deshpande Center at the MIT School of Engineering and the von Liebig Center at the University of California San Diego Jacobs School of Engineering).

\textsuperscript{351} Di Gregorio & Shane, supra note 237, at 213. The Obama administration has signaled its support for proof of concept centers, and it has recently considered appropriating funds to further study and support them. Tedeschi, supra note 349. In the United Kingdom, the national government
Increasingly, universities are taking equity stakes in firms that license their patents, a form of organizational integration that can indirectly foster tacit knowledge exchange. In the past several decades, it has become quite common for universities to take equity as consideration for licenses, particularly from start-ups that lack cash. According to one survey, 23 percent of university technology transfer licenses included some transfer of equity. In another survey, 17 percent of respondents identified licensing for equity as their predominant licensing strategy. Universities obtaining ownership interests in licensee firms represent a very explicit form of integration between academic and commercial entities.

The relationship between obtaining equity stakes and transferring tacit knowledge is somewhat complicated. Unlike in a corporate setting, university administrators cannot simply compel a faculty inventor to work with a firm (in which the university holds equity) that is licensing an academic patent. Nevertheless, equity deals can indirectly foster tacit knowledge transfer. As a general matter, such deals align the interests of universities and licensee firms toward the common goal of commercializing nascent technology. As such, they can mitigate disputes between a university and a licensee if a faculty inventor chooses to devote more time to commercialization efforts. Because equity allows universities to share in the fortunes of entire firms rather than just individual technologies, they may encourage even greater interaction between universities and firms. Not surprisingly, firms that execute an equity-based license generally find it easier to negotiate sponsored research agreements or acquire additional intellectual property rights relative to

sponsors a Teaching Company Scheme that transfers university personnel to work in firms as a means of improving university-industry links. Howells, Technology Transfer, supra note 117, at 102.

352. Di Gregorio & Shane, supra note 237, at 222.

353. Jensen & Thursby, supra note 6, at 246.

354. Markman et al., supra note 319, at 252. Interestingly, experienced technology transfer offices are more than likely to execute equity deals than inexperienced ones. Maryann Feldman et al., Equity and the Technology Transfer Strategies of American Research Universities, 48 MGMT. SCI. 105 (2002).

355. It is important to distinguish between equity stakes held by universities and those held by individual university inventors. While universities routinely take equity stakes, conflict of interest policies at many universities limit equity ownership on the part of faculty members.

356. Independent of enhancing tacit knowledge exchange, equity deals offer several advantages over traditional royalty-based licensing. Equity deals reduce transaction costs relative to traditional licensing, which typically involves a larger set of contingency clauses that contracting parties must negotiate. Feldman et al., supra note 354, at 110. Relatedly, because equity deals contemplate a long-term relationship between a university and a licensee, they facilitate ongoing adjustment and refinement of technology transfer agreements as commercialization takes shape. Id. at 111.

357. Thus universities themselves are not firms, as faculty members are not subject to the same type of hierarchical control as ordinary employees.

358. Id. at 110.

359. Id. at 106.

360. Id. at 110.
other firms.\textsuperscript{361} By helping to build closer relationships between universities and firms, equity stakes encourage the sponsored research and repeat engagements that engender tacit knowledge exchange.

\textit{E. The Industrial Organization of Technology Transfer}

When viewed through the lens of the theory of the firm, university-industry technology transfer appears, at first glance, to be well suited to market-based production rather than vertical integration. The patenting of university inventions—explicitly encouraged by the Bayh-Dole Act—renders possible the buying and selling of academic technologies on the market. Within this traditional conception, the primary conduit for transferring inventions is the contract, or, more precisely, the patent license. Universities and firms can maintain arm’s-length relationships, and faculty inventors largely fade into the background after their initial invention disclosure to a TTO. Vertical integration between universities and commercial firms, which is wholly counterintuitive given their unique natures and normative commitments, does not appear to be necessary to transfer academic technologies.

Market-based technology transfer, however, leaves much to be desired.\textsuperscript{362} Patents do not disclose and licenses do not convey tacit knowledge of great value to licensees. Direct interaction with faculty inventors may significantly accelerate technology transfer, whether because certain technical knowledge is difficult to codify or because real-time, side-by-side problem solving best addresses a specific technical need on the part of the licensee. As such, licensees actively seek relationships with the inventors whose patents they license. Extrapolating from this relational model, formal technology transfer often proceeds in parallel to more intensive organizational linkages spanning academic inventors, universities, and commercial firms.

The theory of the firm can help explain these connections. Transactional hazards related to the noncontractibility of tacit knowledge counsel in favor of organizational integration between technology generators and adopters.\textsuperscript{363} Through a variety of mechanisms, firms are bringing academic human capital in-house to facilitate technology transfer.

While I use the term “vertical integration” to highlight conceptual parallels to the theory of the firm, these organizational arrangements form a continuum of connections. In some instances, upstream academic and

\begin{tabular}{l}
\textsuperscript{361} Id. at 111. \\
\textsuperscript{362} By “market-based technology transfer,” I refer here to licensing markets for university patents. This Article suggests, however, that another type of market—the labor market for the services and expertise of faculty inventors—is quite critical for transferring patented university inventions. \\
\textsuperscript{363} Zucker et al, Commercializing Knowledge, supra note 134, at 150 (“Difficulties inherent to the transfer of tacit knowledge lead to joint research: Team production allows more knowledge capture of tacit, complex discoveries by firm scientists.”); Gorga & Halberstam, supra note 118, at 1203.
\end{tabular}
downstream entrepreneurial functions are completely integrated in the form of university start-ups run by faculty inventors. In other instances, firms may bring faculty inventors in-house by seating them on boards of directors or may simply hire them as consultants. At the far end of the spectrum, sponsored research and sustained engagement with the academic community enhances the absorptive capacity of firms and lays the foundation for effective knowledge transfer.

Such integration reflects “convergence” between the academic and industrial spheres, as illustrated in “exchange of personnel, common research projects, and, in some cases, large-scale joint ventures.” 364 Frequently, technology transfer unfolds within relational networks falling somewhere between the poles of pure contract-based and hierarchical production. 365 Speaking of the biotechnology industry, Walter Powell observes that “[t]he cross-traffic between universities and biotech companies is so extensive and reciprocal that it is appropriate to consider them part of a common technological community.” 366 Private firms, seeking to attract and retain academically oriented scientists, have adopted collegial work cultures that mimic university departments. 367 This intermeshing blurs organizational edges, as one entity, such as a university lab, shades into another, such as a private firm that both licenses an academic patent and sponsors additional research. 368

V. ASSESSMENTS AND PRESCRIPTIONS

While the primary aim of this Article is to provide a descriptive theory of university-industry integration, its findings warrant normative evaluation as well. Having established the importance of tacit knowledge and inventor involvement, this Part assesses the present state of formal technology transfer and offers prescriptions for improving it.

A. Personal Connections, Localism, and Unequal Access

The importance of tacit knowledge and personal interactions within formal technology transfer holds several implications. First, it illustrates the

364. Louis et al., supra note 326, at 114.
365. Cf. Lamoreaux et al., supra note 292, at 408 (“Long-term relationships are sometimes superior to both markets and hierarchies.”); see also Croissant & Smith-Doerr, supra note 96, at 696. See generally Powell et al., supra note 246, at 138–39.
366. Powell, supra note 203, at 200; see Gorga & Halberstam, supra note 118, at 1186. For example, professors in the biomedical sciences often take sabbaticals at biotech companies. Powell et al., supra note 246, at 123; see also Murray, Laboratory Life, supra note 138, at 654.
367. See Kenney, supra note 287, at 177–82; Paul Rabinow, Reflections on Fieldwork in Alameda, in TECHNOLOGICAL IMAGINARIES: CONVERSATIONS, PROFILES, AND MEMOIRS 155 (George E. Marcus ed., 1995) (discussing the experience of several scientists at Cetus).
368. Dasgupta & David, supra note 114, at 516 (noting the possibility of “[r]eadjusting institutional norms to enlarge the social boundaries of the research community, as a way of facilitating the transfer of new findings from academic science to industrial laboratories”).
deeply human, dialogic, and relational nature of “formal” technology transfer. Commentators have long recognized that academic technical knowledge diffuses to the private sector in a variety of ways, many of which are rather informal and operate independently of the patent system. Patenting and licensing seek to formalize this process, but these activities in and of themselves are often insufficient to transfer a technology. Indeed, the effectiveness of formal technology transfer often depends on more fluid, idiosyncratic systems of personal connections and tacit knowledge exchange to support it. As opposed to a scheme in which discrete market transactions transfer fully disclosed inventions between strangers, formal technology transfer is often a messy, imprecise endeavor that features intensive knowledge exchange within long-term relationships. As such, legal and policy interventions that focus only on enhancing patenting and licensing may be quite limited in their ability to improve technology transfer overall.

In some respects, the ways in which formal technology transfer deviates from the market-oriented model are rather troubling. For example, the findings of this Article suggest that the mechanisms facilitating formal technology transfer are quite conservative. Personal networks on the part of both TTO officials and faculty inventors are critical to finding licensing partners, thus favoring well-positioned individuals who already have extensive industry contacts. Inventions by newer scientists or those without wide networks may receive less attention in a “formal” technology transfer system in which informal connections matter a great deal.

More broadly, the importance of personal interactions and tacit knowledge transfer illustrates the deficiencies of patents as public sources of technical information. While patent disclosures are not “product specifications,” they nonetheless aim to adequately describe an invention, enable a technical artisan to make and use it, and explain any best mode for practicing it. In this sense, patents are “democratic” documents that seek to disclose an invention to the public at large. However, patent disclosures may omit much technical knowledge valuable for appropriating a basic invention. Furthermore, they do not even aim to include a host of technical information relevant for extending, refining, or adapting a technology for commercial purposes. Contrary to the democratic character of patents, such lacunae allow individual inventors—whether acting strategically or not—to retain private information about their technologies, which they can then communicate in private channels to select parties.

369. See supra note 16 and accompanying text.
370. See supra Part IV.
371. Cf. Robert K. Merton, The Matthew Effect in Science, 159 SCIENCE 56, 58 (1968) (finding that higher-prestige scientists are more likely to have articles cited than lower-prestige scientists, even when their articles are of equal academic importance).
372. See supra Part I.A.
As a related matter, formal technology transfer tends to unfold in regional networks rather than truly national licensing markets, thus giving rise to potential geographic inequities.\textsuperscript{373} The personal and tacit nature of technology transfer, as well as institutional commitments to local economic development, helps explain why universities tend to license to companies in their immediate vicinity. However, given the Bayh-Dole Act’s aim of putting federal research dollars to good use, ostensibly to promote national economic development, such geographic clustering gives rise to troubling distributive inequalities in technology transfer and innovation. Firms located near major research universities will be the primary drivers of commercialization arising from federally funded research.

\textbf{B. The Inefficiency of Enhancing Patent Disclosure}

One policy response to the challenge of transferring tacit knowledge—and one that is consistent with a market-based conception of formal technology transfer—is to enhance the disclosure requirements for obtaining a patent. For example, Congress might amend the Patent Act to require greater disclosure on the part of patent applicants, or courts could more stringently interpret existing doctrines mandating disclosure. Requiring greater codification of (formerly) tacit knowledge would in theory mitigate the need to engage directly with inventors, thus disentangling patent licensing from local, relational networks. Enhanced disclosure, moreover, would be consistent with legal principles suggesting that patentees should not enjoy exclusive rights while concealing useful information about their inventions.\textsuperscript{374} Interestingly, this proposal would run contrary to recent legislative changes that decrease disclosure requirements by weakening the best mode requirement.\textsuperscript{375}

However, it is doubtful that enhancing patent disclosure would improve the overall efficiency of formal technology transfer. While disclosing more (formerly) tacit information in a patent may ease the adoption of technology by a licensee, such a requirement would substantially increase costs for patentees.\textsuperscript{376} Tacit knowledge is, by definition, impossible or costly to codify, and heightened disclosure requirements would greatly enhance the expense and complexity of obtaining a patent.\textsuperscript{377}

\textsuperscript{373} Furthermore, “prestigious” universities tend to license at higher rates than their prior commercial success would predict. Wesley David Sine et al., \textit{The Halo Effect and Technology Licensing: The Influence of Institutional Prestige on the Licensing of University Inventions}, 49 MGMT. SCI. 478, 491–95 (2003).

\textsuperscript{374} See, e.g., \textit{In re Gay}, 309 F.2d 769, 772 (C.C.P.A. 1962).

\textsuperscript{375} See Leahy-Smith America Invents Act of 2011, Pub. L. No. 112-29, 125 Stat. 284 (codified in scattered sections of 35 U.S.C.) (eliminating the failure to disclose a best mode as a ground for invalidating a patent in litigation or reexamination proceedings).

\textsuperscript{376} See Dasgupta & David, \textit{supra} note 114, at 502.

\textsuperscript{377} Some commentators have eschewed the normative vision of patent disclosure as a rich source of technical information, arguing that it should simply provide enough information to render claims legally understandable. Within this view, efforts to enhance the disclosure requirements of
More importantly, it is doubtful that enhanced patent disclosure would divulge the precise tacit knowledge of interest to a particular licensee. Much tacit knowledge sought by licensees concerns not the basic operation of a patented invention, but how to refine or adapt an invention to novel contexts. More broadly, gleaning information from static text is qualitatively different from having an interactive conversation; there is sometimes no substitute for directly talking with an inventor about her creation. In this sense, tacit knowledge has an “emergent” character in that it is often best elicited and articulated through social interaction and dialogue. Additionally, an enhanced disclosure requirement may motivate highly inefficient “data dumps” of tacit information, much of which is not particularly useful yet is expensive to codify. Indeed, it would be very difficult for the Patent and Trademark Office to ascertain the adequacy of tacit knowledge disclosure given that a PTO examiner cannot know the subjective contents of an inventor’s mind.

In terms of maximizing efficiency, a tradeoff thus arises with regard to enhancing patent disclosure. Heightened tacit knowledge disclosure may or may not ease the ex post adoption of technology by licensees, but it will certainly impose high ex ante costs on inventors. At some point, local, interaction-based modes of tacit knowledge transfer represent more efficient means for transmitting technical information than enhanced codification in patents.378 While interpersonal tacit knowledge transfer is highly expensive and tends to exacerbate spatial inequalities in technology transfer,379 this may simply represent a “cost of doing business” that licensors and licensees must absorb to effectively transfer particular technologies.

C. Enhancing and Expanding Relational Technology Transfer

Given their efficiency benefits, personal relationships and organizational integration should and arguably must remain important conduits for transferring patent-related tacit knowledge to the private sector. These activities have their drawbacks and limitations, however, and this Article proposes several reforms to improve them. Perhaps unsurprisingly, these proposals are aimed not at high-level statutory frameworks such as the Patent Act or the Bayh-Dole Act but at the policies and procedures of individual funding agencies and universities.380 Given the decentralized nature of technology patent law would “raise the cost and complexity of patents without increasing the amount of economically meaningful information disseminated.” Kitch, supra note 51, at 288.


379. Shane, Encouraging University Entrepreneurship?, supra note 265, at 131.

380. Cf. Sara Boettiger & Alan B. Bennett, Bayh-Dole: If We Knew Then What We Know Now, 24 NATURE BIOTECHNOLOGY 320, 320 (2006) (arguing that many of the deficiencies of university-industry technology transfer did not arise from the Bayh-Dole Act itself but from the policies of individual institutions implementing it).
transfer, policy interventions at the local level are likely to significantly impact
the efficacy of transfer activities.

When financing research likely to lead to patentable inventions, federal
agencies should allocate specific funding for technology transfer activities on
the part of grant recipients. This proposal would be particularly relevant to
NIH, which provides substantial funding for biomedical research that often has
commercial applications. These funds would support additional research and
refinement of a patented invention, thereby allowing the academic inventor to
to better adapt the technology to commercial use prior to licensing. Additionally,
even after licensing, these funds would support ongoing research and
interactions between the academic inventor and the licensing entity. Here,
the Stevenson-Wydler Act, which regulates technology transfer from national
laboratories to private firms, offers an illustrative guide. This statute, which
was passed alongside the Bayh-Dole Act, requires that national laboratories set
aside 0.05 percent of research budgets to support transfer activities. If
technology transfer is a high priority, then federal agencies should fund it
directly.

Turning to universities, the relational nature of technology transfer
suggests an increased emphasis on partnership building for TTOs. These
offices have historically focused on patenting and licensing, as evidenced by
their being staffed, at least in part, by licensing professionals and attorneys.
While scientific and legal expertise is obviously critical to TTOs, the
importance of fostering relationships with commercial partners suggests
leveraging other types of expertise as well. Such offices serve as valuable
“boundary spanning” entities, and the ability to network and build relationships
between scientists and industry is a critical skill. In particular, TTOs can help
bridge a perceived cultural gap between academia and industry. Surveys of
relevant stakeholders reveal that “[l]ack of understanding regarding university,
corporate, or scientific norms and environments” constitutes the leading barrier

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381. NIH invests over $30.9 billion in medical research. See NIH Budget, NAT’L INSTS. OF
382. Relatedly, commentators have also suggested that NIH and other funding agencies offer
greater support for “translational,” as opposed to basic, research. See, e.g., Pisano, Can Science Be a
    Business?, supra note 29, at 12.
383. See Bozeman, supra note 8, at 644.
384. Cf. Zucker & Darby, supra note 1, at 12,711 (“[W]hen information transfer between
    organizations is desired, boundary spanning mechanisms are vital, creating a demand for social
    structure that produces ties between scientists across these boundaries.”).
385. See Bo Carlsson & Ann-Charlotte Fridh, Technology Transfer in United States
    Universities, 12 J. EVOLUTIONARY ECON. 199, 205–08 (2002).
386. Siegel et al., Effective Transfer, supra note 5, at 121; see Irwin & More, supra note 15, at
    278; Siegel et al., Assessing the Impact, supra note 106, at 45; Owen-Smith & Powell, supra note 105,
    at 613–14.
387. See, e.g., Lee, ‘Technology Transfer,’ supra note 7, at 845 (describing the “two cultures’
    problem” of “normative and attitudinal differences separating universities from industry”); Fraser,
supra note 5, at 17.
to university-industry technology transfer. 388 As such, TTOs should augment their legal expertise with persons possessing marketing, development, and entrepreneurial experience who can help develop long-term relationships with commercial partners and mediate potential conflicts. By “formalizing” the relationship-building process, TTOs can play a particularly salutary role in marketing technologies created by faculty inventors who lack extensive personal contacts with industry.

More concretely, universities can accelerate tacit knowledge transfer by creating “Knowledge Transfer Centers.” Such centers would provide services complementary to that of traditional proof of concept centers and TTOs. First, they would provide financial and material support for academic inventors to voluntarily develop embryonic inventions into prototypes that are more readily commercialized by private firms. Once an invention is patented and a licensee is secured, Knowledge Transfer Centers would then create physical and virtual spaces for university inventors to continue interactions and tacit knowledge transfer with licensees. For example, after the parties have executed a license, the inventor and the licensee’s technical personnel could utilize university laboratory and testing resources coordinated by Knowledge Transfer Centers to collaboratively refine and develop a technology before transferring operations to the licensee firm. This emphasis on postlicensing collaboration would distinguish Knowledge Transfer Centers from traditional proof of concept centers, which tend to focus on developing a commercialization plan before a licensee is on board and introducing inventors to prospective commercial partners. 389 By serving as a “nursery” instead of just an “incubator” for new inventions, 390 these centers would facilitate tacit knowledge transfer and commercialization of patented academic technologies.

Additionally, universities could implement several other structural changes to promote commercialization, though they must be approached with care. Greater sponsored research, joint research partnerships and centers, industrial affiliate programs, and personnel exchanges between academia and industry would all accelerate tacit knowledge transfer. 391 To maximize commercialization, a university could in theory take more aggressive measures, such as enhancing the proportion of royalties awarded to faculty inventors 392 or even expanding opportunities for faculty inventors to take equity in licensee

388. Siegel et al., Effective Transfer, supra note 5, at 128.
390. I am indebted to Mario Biagioli for this terminology.
391. See Kenney, supra note 287, at 37–54 (describing many types of university-industry connections); Louis et al., supra note 326, at 114.
392. Jensen & Thursby, supra note 6, at 255; cf. Albert N. Link & Donald S. Siegel, Generating Science-Based Growth: An Econometric Analysis of the Impact of Organizational Incentives on University-Industry Technology Transfer, 11 EUR. J. FINANCE 169, 179 (2005) (finding that universities allocating a higher percentage of royalties to faculty inventors are more productive in technology transfer activities).
firms. After all, the participation of academic inventors in commercialization is most effective when inventors have strong incentives to improve firm performance. While such measures would enhance faculty-industry knowledge exchange, they must be balanced against the traditional normative objectives of universities and faculty scientists, discussed at length below.

D. Cultural Conflict and Normative Limits on Organizational Integration

As a descriptive matter, this Article has shown that close working interactions between faculty inventors and commercial licensees are often critical to transferring patented university inventions to the private sector. Following from this finding, the preceding Section described various institutional reforms to help universities, faculty inventors, and licensees better exploit personal interactions and organizational integration to effectuate formal technology transfer. Indeed, in proposing the creation of Knowledge Transfer Centers, the Article has called for even closer connections between academia and industry. However, greater university-industry convergence gives rise to a host of serious concerns over the commercialization of academia. While university-industry linkages provide valuable pathways for tacit knowledge transfer, cultural and institutional considerations provide a normative constraint on the degree to which universities and faculty inventors should be integrated with commercial enterprises.

Observers have long been suspicious of close connections between universities and industry, noting a variety of intersecting concerns. For example, profit motives may alter research agendas in favor of more commercially promising rather than scientifically valuable lines of inquiry.

393. Jensen & Thursby, supra note 6, at 255. While I include these options for analytical completeness, I do not necessarily endorse them. As argued below, universities should place appropriate limits on faculty compensation from technology transfer activities. See infra notes 424–426 and accompanying text.


395. See infra Part V.D.

396. See supra notes 384–94 and accompanying text.

397. See Murray, Innovation as Co-evolution, supra note 304, at 1402; cf. Owen-Smith & Powell, supra note 105, at 609 (noting that universities often espouse a “logic of discovery” while for-profit organizations favor more “closed,” proprietary logics).

398. See generally DEREK BOK, UNIVERSITIES IN THE MARKETPLACE: THE COMMERCIALIZATION OF HIGHER EDUCATION (2003); CAPITALIZING KNOWLEDGE: NEW INTERSECTIONS OF INDUSTRY AND ACADEMIA (Henry Etzkowitz et al. eds., 1998); JENNIFER WASHBURN, UNIVERSITY, INC.: THE CORPORATE CORRUPTION OF AMERICAN HIGHER EDUCATION (2005); Rebecca S. Eisenberg, Academic Freedom and Academic Values in Sponsored Research, 66 Tex. L. Rev. 1363, 1363 (1988) [hereinafter Eisenberg, Academic Freedom]; Gelijns & Thier, supra note 17, at 77 (describing the differing missions, cultures, resources, and incentives of commercial firms and universities); Lee, Technology Transfer, supra note 7, at 857.

Pursuing commercial research may also decrease academic productivity, bias investigations, and create incentives to manipulate research results. Commercialization efforts by academic scientists may produce conflicts of interest, weaken academic freedom, undermine the teaching and mentoring of students, and even decrease public confidence in universities. Additionally, university-industry links can have larger, less appreciated structural effects. Universities have wrestled with these and related issues for centuries.

Commentators have particularly criticized sponsored research arrangements that approach true integration of universities and private companies. The governance structures of sponsored research arrangements may sometimes grant corporate sponsors significant control over the types of


400. See David Blumenthal et al., Participation of Life-Science Faculty in Research Relationships with Industry, 335 NEW ENG. J. MED. 1734, 1738 (1996).


402. See Press & Washburn, supra note 399, at 42.

403. David J. Triggle, Patenting the Sun: Enclosing the Scientific Commons and Transforming the University—Ethical Concerns, 63 DRUG DEV. RES. 139, 143–44 (2005) (describing conflicts of interest between faculty members and universities); KENNEY, supra note 287, at 115 (describing a potential conflict of interest wherein Herbert Boyer, a Genentech cofounder, obtained a $200,000 research grant from Genentech).


405. KENNEY, supra note 287, at 117–21.

406. Triggle, supra note 403, at 144–45.

407. For instance, labor shortages in the biotechnology industry may drive larger graduate programs in the life sciences, leading to an oversupply of Ph.D.s with limited prospects for academic careers. See KENNEY, supra note 287, at 6.

408. For example, the establishment of land-grant colleges in the nineteenth century fueled debates over the degree to which universities should solve practical problems as opposed to pursue “philosophical” inquiry. See Carstensen, supra note 3; see also C.J. HAMSON, PATENT RIGHTS FOR SCIENTIFIC DISCOVERIES 168 (1930) (“As far as is possible, the scientist should have no direct relations with the manufacturer. Such separation is to the convenience of both. The scientist would perhaps be distracted in his technical researches by any necessity to negotiate settlements, while the manufacturer would be embarrassed by demands from unexpected individuals.”); Sampat, supra note 17, at 776; Hughes, supra note 331, at 547; Argyres & Liebeskind, supra note 3, at 444; cf. Argyres & Liebeskind, supra note 3, at 452 (“Universities, like other organizations, are discrete structures, and find it very difficult to support multiple social goals simultaneously.”).

409. KENNEY, supra note 287, at 89 (“[T]he large contracts between universities and industry, the increased exclusive licensing of innovations, and the participation by some universities in small companies encourage doubt as to whether the university as an institution is independent of industry ethically and morally.”); see Eisenberg, Academic Freedom, supra note 398, at 1363.
projects that faculty members can pursue. Furthermore, commercial sponsors of academic research sometimes seek to review drafts of scientific manuscripts and delay publication. In some instances, sponsors may favor outright secrecy over publication of research findings, thus contravening the open, public ethos of academic science. Universities have long grappled with these issues; MIT, for example, experienced significant internal and external controversy when it established the Whitehead Institute in the early 1980s.

The impact of commercial influences on universities is, of course, an enormous issue that this Article does not seek to resolve. Nonetheless, it is appropriate to highlight a few salient points. In certain contexts, there is no necessary conflict between pursuing basic scientific knowledge and engaging in research with immediate commercial applications. As commentators have noted, much university research (particularly in biomedicine) proceeds in “Pasteur’s quadrant”: while it strives for deep scientific understanding, it is also intrinsically oriented toward practical applications. Indeed, conducting pragmatic research, as well as grappling with the technical challenges of commercializing embryonic inventions, may reveal fundamental insights and new lines of inquiry of high scientific value.

In addition, commercial influences on academic research must be evaluated with a sense of proportion. While consulting fees may distort incentives on the part of academic scientists, average compensation received by faculty consultants in almost every field is less than one-tenth of their average academic salary. Furthermore, Derek Bok observes that “[w]hile corporate support has grown, it still makes up less than 10 percent of all university research and hence does not significantly affect the overall balance of priorities.” Overall, according to Bok, “Two decades of experience reveals...”

410. See Washburn, supra note 307 (describing BP’s influential role in setting research agendas and disbursing funds in a sponsored research agreement with UC Berkeley, Lawrence Berkeley National Laboratory, and the University of Illinois at Urbana-Champaign).

411. See Argyres & Liebeskind, supra note 3, at 439–40 (describing such an arrangement involving Hoechst, which sponsored research at Massachusetts General Hospital); Kenney, supra note 287, at 61–64 (same); id. at 60 (noting that the MIT-Exxon agreement provides for a ninety-day delay in publication for patent filings and constrains presentations at professional meetings). Some commercial sponsors even ghostwrite academic manuscripts. Bok, supra note 398, at 72.

412. See Eisenberg, Academic Freedom, supra note 398, at 1375.

413. Kenney, supra note 287, at 50–51.

414. Indeed, empirical studies have shown that scientifically productive scholars are more likely to engage in entrepreneurial activities. Louis et al., supra note 326, at 127.


416. See, e.g., Bito, supra note 182, at 1130–31 (noting that development of prostaglandins into a commercial glaucoma therapy spurred new academic inquiries into melanin).


418. Bok, supra note 398, at 60.
no significant tendency to abandon basic research for more profitable kinds of applied or practical work.”

More broadly, commercially oriented activities may be fully consistent with the missions of particular universities. For instance, many state universities trace their roots to the Morrill Acts, which established land-grant institutions with a decidedly pragmatic character. Indeed, MIT, Georgia Tech, and many land-grant universities view technology transfer as indelibly linked with their social obligations as universities. Along these lines, commentators have called for “‘neotransferism’—a return to the landgrant philosophy with a renewed emphasis on the transfer to industry of knowledge, technology, know-how, and trained people in the interest of economic development.” Ultimately, individual universities must decide whether and to what extent to embrace commercially oriented activities based on institutional objectives, public deliberation, and shared governance.

That being said, if universities are to retain their unique social and cultural character, they should establish important safeguards against undue integration with commercial entities. For example, universities should follow the example of some institutions that limit faculty consulting to one day a week. Although it is admittedly difficult to monitor and enforce these restrictions, anecdotal evidence suggests that most faculty members comply. Furthermore, universities should limit faculty members’ ability to take managerial roles in outside ventures and own equity in firms that provide research funds, as the University of California, Harvard, Stanford, and MIT have done. The goal is to create an environment where professors may interact, sometimes intensively, with private licensees, but do so in a way that does not alter research agendas, create conflicts of interest, or give corporate sponsors undue influence over academic inquiry.

Universities should also implement safeguards for sponsored research agreements. Universities should restrict “secret” research and limit publication delays to a minimum, reasonable period of time. Furthermore,

419. Id. at 142.
422. Id. at 850.
424. Argyres & Liebeschkind, supra note 3, at 450 (noting such a policy at the University of California and Stanford University).
426. Argyres & Liebeschkind, supra note 3, at 449.
427. Several universities have already had these policies for years. See Eisenberg, Academic Freedom, supra note 398, at 1393.
428. See BOK, supra note 398, at 143–44 (suggesting that corporate sponsors should not be able to delay publication more than two or three months after research has ended).
universities should insist on governance structures for sponsored research agreements whereby sponsors do not exert undue influence over research agendas. Universities can help do so by reserving a majority of seats on boards or committees charged with allocating research funds. More broadly, well-articulated conflict of interest policies may help ensure that faculty members retain their academic objectivity when dealing with commercial licensees.

Given the unique normative commitments, cultural orientations, and social roles of universities and private firms, it is unlikely that complete integration of the two is either desirable or possible. University-industry technology transfer thus offers an interesting cultural twist on the theory of the firm; notwithstanding information efficiencies of vertical integration, cultural norms provide a stark impediment to true integration. Abstracting away from complete institutional integration, however, this Article shows that a wide range of intermediate linkages provide valuable conduits for patent-related (and non-patent-related) technical information exchange between academia and industry. The key is to strike a prudent balance. As reflected in President Obama’s remarks, the economic and technological challenges of the day suggest that university research may legitimately serve both disinterested academic inquiry and more practical concerns. Universities and academic scientists are well suited to serve this hybrid interest, as history shows them to be “pragmatic[] and open-minded to new national imperatives.” Within important limits, organizational integration among universities, academic inventors, and firms can serve as a valuable mechanism for enhancing information dissemination and the commercialization of publicly sponsored technologies.

VI. THEORETICAL IMPLICATIONS

The importance of local, human-based avenues of technical knowledge transfer raises important implications for intellectual property theory and the nature of the firm.

429. See Washburn, supra note 307 (criticizing BP’s role in selecting a director and other high-level positions for the Energy Biosciences Institute as part of $500 million in sponsored research at UC Berkeley, Lawrence Berkeley National Laboratory, and the University of Illinois at Urbana Champaign).

430. See, e.g., Bok, supra note 398, at 151–52 (describing the 1998 agreement between Novartis and UC Berkeley’s Department of Plant and Microbial Biology, in which Novartis obtained two of five seats on the committee awarding funds). Retaining a majority of seats, however, may not be sufficient to ensure the fidelity of funding decisions, as faculty members may still be induced to support projects favored by corporate sponsors.

431. Lee, Technology Transfer, supra note 7, at 859.
A. The Limitations of Intellectual Property

This study of tacit knowledge sheds new light on the relationships among patents, technology transactions, and vertical integration. Recent scholarship has highlighted the role of patents in mitigating transactional hazards, thus facilitating technology transactions between independent parties.\textsuperscript{432} Drawing on these analyses, commentators have argued that patents enable the independent existence of small, research-based firms that can license patents to larger companies; in the absence of patents, smaller firms would likely be vertically integrated into the larger concerns.\textsuperscript{433} However, the enduring importance of tacit knowledge challenges the sufficiency of patent licensing alone to promote technology transactions\textsuperscript{434} as well as the discreteness of transacting parties. Extrapolating beyond formal university-industry technology transfer to licensing more generally, even where parties license patent rights, they may have to engage in some degree of organizational integration to truly transfer a technology.\textsuperscript{435}

These observations relate more generally to the forces (and deficiencies) that motivate organizational integration. According to the theory of the firm, the incompleteness of contracts leads to vertical integration of two formerly independent parties. Patents mitigate this transactional hazard, thereby easing technology transactions. However, intellectual property itself can be incomplete by not disclosing tacit knowledge crucial to exploiting an invention. Vertical integration thus arises not simply from the incompleteness of contracts, but also from the incompleteness of (intellectual) property. Of course, commentators have long recognized that “weak” intellectual property rights may lead to vertical integration.\textsuperscript{436} This weakness, however, typically relates to uncertainty regarding the scope, validity, and enforceability of rights, thus raising expropriation risk. The incompleteness identified here is of a different sort altogether, relating instead to the knowledge deficits resulting from incomplete patent disclosure in the context of technology transfer.

\textsuperscript{432} See, e.g., Heald, \textit{supra} note 267; Kieff, \textit{supra} note 99; Merges, \textit{Transactional View}, \textit{supra} note 77.


\textsuperscript{434} See Arora & Merges, \textit{supra} note 275, at 454 (noting that patenting and licensing can contribute to “unsticking” knowledge and fostering other forms of information exchange between parties).

\textsuperscript{435} This thesis thus illustrates the other end of the continuum of Arora and Merges’s analysis. Patents facilitate the existence of independent firms and enable direct and indirect knowledge exchange with subsequent parties. At some point, however, patent-mediated information exchange may not satisfy knowledge demands on the part of a licensee, thus weighing in favor of vertical integration. \textit{See id}.

In unexpected ways, these knowledge deficits also shed new light on a topic that has gained substantial attention in patent reform discussions: nonpracticing entities (NPEs). NPEs, pejoratively called “patent trolls,” accumulate patent portfolios but do not manufacture products, relying on licensing revenues and the threat of patent enforcement for income. Against criticisms that NPEs simply tax innovation with little countervailing social gain, some commentators have defended NPEs as “market makers” for patented technologies. The importance of tacit knowledge, however, casts doubt on the ability of NPEs to function as technology transfer intermediaries. (Whether they strive to function as such is, of course, also debatable.) NPEs represent the epitome of market-based technology transfer in that patent rights are owned by a holding company that is completely divorced from the original inventor. While NPEs may transfer the bare legal right to practice some invention, their ability to transfer tacit knowledge that greatly enhances an invention’s exploitation is severely limited. Thus, the claim that NPEs serve as effective market mediators may require serious reassessment.

B. The Firm, the Commons, and Internal Information Transfer

This Article also offers a new perspective on the role of firms and organizational integration in facilitating technical knowledge transfer. Classic conceptions of the theory of the firm locate the benefits of vertical integration in the hierarchical, command-and-control nature of firm production. Arm’s-length, market contracting is susceptible to a variety of opportunistic threats, such as when one contracting party exploits another party’s investments in deal-oriented specialization. Vertical integration within a single firm resolves these contractual hazards by bringing both parties in-house, where central management can ensure that neither the technology generator nor the user behaves strategically. In this classic formulation, it is the autocratic nature of firms (as opposed to market-based production) that is the primary benefit of vertical integration.

However, in resolving transactional hazards related to conveying tacit knowledge, very different properties of the firm are implicated. It is not the autocratic nature of firms that facilitates internal information dissemination so
much as the reduced barriers to communication within a single organization. 441

In important ways, firms function as a bounded knowledge commons in which “internal” technology producers and adopters can freely meet, discuss, and exchange information. 442 This is a qualitatively different commons than the repository of publicly available information generated through patent disclosures. Rather than an “invisible college of technology,” 443 this is a human, tactile commons that facilitates the “sociability” that drives interpersonal interaction and exchange. 444 In particular, bringing a faculty inventor in-house enables the chance encounters, directed conversations, and long-term, side-by-side research that facilitate tacit knowledge transfer. 445

Ultimately, it is the communal, rather than autocratic, nature of organizations that accounts for the learning benefits of vertical integration.

**C. Tacit Knowledge and Patent Economics**

These reflections on technology transfer and tacit knowledge also hold broader implications for patent law and theory. According to classic patent theory, technical information is a public good that is both nonrival and nonexcludable and thus subject to undersupply in a competitive economy. 446 Patents resolve this market failure by granting patentees a legal right to exclude others from practicing protected inventions, thus maintaining incentives to invent.

The tacit nature of much technical knowledge, however, challenges the public-good character of information. In large part, tacit knowledge is naturally excludable. 447 While a master chef “knows” how to prepare a difficult soufflé, this information resides primarily in his or her mind (or muscle memory) and cannot be easily communicated, much less appropriated without authorization. The difficulties of transmitting tacit knowledge also call into question the rivalrous nature of such information. The knowledge of how to make a soufflé is technically nonrival in that multiple parties can simultaneously exploit it.

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441. Of course, the autocratic nature of firms may still be helpful in one regard: if a faculty inventor is brought in-house, the management of a technology company can “compel” (with the threat of dismissal) that inventor to disclose tacit knowledge related to a patent that it is licensing. Cf. Gorga & Halberstam, supra note 118, at 1165.


443. Cooper, supra note 75, at 40.

444. See Rose, *Comedy of the Commons*, supra note 442, at 723, 774–81.

445. See Alcácer & Chung, supra note 215, at 762.


without diminishing its availability for others. However, if communicating this knowledge requires direct personal interaction and side-by-side cooking sessions, then in some meaningful sense, this knowledge exhibits scarcity. Human time and labor are certainly rivalrous, and to the extent that communicating tacit knowledge requires significant personal effort, such knowledge is rivalrous.

Tacit knowledge thus complicates traditional justifications for patents. A primary rationale for extending exclusive rights over inventions is to guard against unauthorized expropriation of technical knowledge, which outside parties can appropriate at little or no cost. However, given that tacit knowledge is naturally excludable and competitors cannot easily appropriate it for free, the rationale for extending exclusive rights over such knowledge loses considerable force. Indeed, patentees may enjoy a windfall when they can obtain exclusive rights over their inventions while still retaining tacit knowledge of value to downstream technology users.

One might suspect that even in the absence of exclusive rights, robust incentives exist to develop tacit knowledge given that it is both highly valuable and naturally excludable. However, here tacit knowledge faces a different appropriability problem: it is too difficult to transmit. Tacit knowledge is not directly contractible: someone who possesses tacit knowledge cannot codify and convey it to another within a contractual agreement. The difficulties of conveying tacit knowledge, moreover, undermine the ability of inventors to sell it on the market, which in turn may chill incentives to develop it in the first place. Turning patent theory on its head, it is the difficulty of transmitting tacit knowledge that may lead to problems of underproduction.

Given that inventors cannot neatly package and sell tacit knowledge, how can they derive revenue from it? By offering their own personal time and services. Thus, inventive activity creates both classic, “public good” technical knowledge as well as rivalrous, naturally excludable human capital. Patents and licenses transfer the former, but parties transfer the latter through direct relationships, consulting agreements, and absorption into downstream firms. Effective technology transfer must exploit not only formal markets for patented inventions but also relational and organizational mechanisms for unlocking the uncodified knowledge residing in inventors’ minds.


449. Cf. Cowan et al., supra note 113, at 224 (“By implication, the patent system’s exchange of monopoly of use for ‘disclosure’ allows the patentee to retain the tacit knowledge without which the information contained in the patent really is useless.”).

450. Cf. Lowe, supra note 148, at 416 (“[W]hen the knowledge related to an invention is largely tacit, an inventor can extract full monopoly profits related to an invention.”).

451. Zucker et al., Intellectual Human Capital, supra note 125, at 291; Zucker et al., Commercializing Knowledge, supra note 134, at 141.
CONCLUSION

Classic patent and technology transfer theories posit that markets facilitate low-cost transfers of patented inventions from licensors to licensees. Undergirding this view is a related presumption that patent disclosure is sufficient to exploit a patented invention, thus reducing technology transfer to the mere act of exchanging patent rights for consideration. Drawing on empirical studies of university-industry technology transfer, this Article challenges and refines this model. It shows that licensing markets, particularly for early-stage university inventions, are strikingly thin. More substantively, this Article highlights the importance of tacit knowledge in effectively transferring patented university technologies to private firms. Even where a patent satisfies the legal requirements of disclosure, much valuable knowledge related to an invention resides, in tacit form, in the inventor’s mind.

While licensing markets are certainly important, they are often supplemented by personal relationships in transferring technologies from universities to private firms. Personal networks are crucial to identifying licensees, and the ongoing involvement of faculty inventors is particularly critical to transferring patent-related tacit knowledge to downstream firms.

Ultimately, relationships between universities and faculty inventors, on the one hand, and licensee firms, on the other, can mature into deeper organizational links. This Article has drawn from the theory of the firm to highlight transactional hazards in university-industry technology transfer. These hazards typically do not arise from the standard opportunistic behavior of two for-profit entities seeking to maximize rents. Rather, they arise from the difficulties of conveying tacit knowledge. These difficulties, moreover, help motivate firms to directly engage and sometimes integrate academic human capital into their operations. Through a continuum of linkages ranging from informal networks to consulting engagements to outright consolidation of academic and entrepreneurial functions in university start-ups, private firms are bringing academic inventors and their tacit knowledge in-house to aid in commercializing university inventions. These organizational innovations, moreover, tend to blur the institutional boundaries between universities and firms. While such convergence generates serious concerns over undue commercial influences in academia, with appropriate support and safeguards, relationships and organizational integration can serve as important vehicles for transferring tacit knowledge and realizing the promise of university-based innovation.