KNOWLEDGE INPUTS, LEGAL INSTITUTIONS AND FIRM STRUCTURE: TOWARDS A KNOWLEDGE-BASED THEORY OF THE FIRM

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ABSTRACT

Corporate scholars rely on traditional theories of the firm to analyze corporate organization and corporate contracting. However, traditional theories of the firm, as the authors argue, are incomplete in that they neglect the role that knowledge plays in shaping the internal structure of a firm. The article proceeds to address this gap by focusing on knowledge resources as a key influence on internal corporate governance structures. First the authors introduce a new typology that explains firm internal governance structure based on the types of knowledge used in the production process. Then they analyze the interaction of law and knowledge management. They go on to show how certain legal mechanisms, such as patents, trade secrets, and private contracting (e.g. covenants not to compete) emerged as tools for binding knowledge to the firm. They propose a principle of efficient knowledge allocation, positing that organizational structures must maximize the use of knowledge resources against the background of specific hazards that affect transactions involving knowledge inputs. Applying these theoretical constructs, the authors show how the management of knowledge resources required in mass production, high tech and law firms differentially affect the decisional hierarchies of these types of firms and also their compensation and ownership structure in certain instances. More specifically, the authors argue (1) that a shift in knowledge requirements drove the changes in the organizational structure of mass production firms from the C-form to the M-form, affecting decision-making powers; (2) that the adoption of stock option plans in high-tech firms controls knowledge hazards (stock options prevent leakage by retaining individual knowledge and discouraging hoarding of knowledge); (3) that profit splitting and the partners-associate hierarchy in law firms reflects the need to maximize the use of knowledge resources and that changing knowledge requirements are affecting law firm organization; and finally, (4) that certain business transactions like mergers, joint ventures and licensing contracts are shaped by knowledge inputs. The authors conclude that knowledge considerations provide policy makers with a positive explanation for firm structure and a normative perspective counseling greater attention to the effects of regulation on knowledge allocation within firms.

"An explanation of when, why, and how managerial hierarchies developed in certain industries and rarely appeared in others remains a challenge to economists, sociologists, practitioners of management science, and economic and business historians."

— Alfred Chandler & Herman Daems, *Managerial Hierarchies: Comparative Perspectives*[†]

"Considering the acknowledged importance of knowledge and competence in business strategy and indeed the entire system of contemporary human society, it is striking that there seems to be a paucity of language useful for discussing the subject . . . . [T]here seems to be a serious dearth of appropriate terminology and conceptual schemes."

— Sidney G. Winter, *Knowledge and Competence As Strategic Assets*[‡]

INTRODUCTION

The literature on the theory of the firm and corporate organization has treated extensively different variables that affect firm boundaries and internal corporate structure. Economists and corporate law scholars have thus accounted for changes in firm structure with explanations based on transaction costs,[1] agency costs,[2] and property rights over physical assets.[3]

This literature, however, has largely ignored one very important variable: *knowledge resources* that firms use in the production process. This variable concerns perhaps the core ingredient firms rely upon to achieve their objective of generating products and services that will be sold on the market. Indeed, knowledge resources are tantamount to the whole business enterprise. However, a theory that focuses on how firms deploy knowledge resources in the production process, and on how that deployment, in turn, has differential effects on firm internal organization is absent in traditional economic explanations and in the legal literature.

This Article begins to fill the gap. We argue that one cannot explain the organization of business firms without reference to the knowledge struc-

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[†] ALFRED CHANDLER & HERMAN DAEMS, MANAGERIAL HIERARCHIES: COMPARATIVE PERSPECTIVES ON THE RISE OF THE MODERN INDUSTRIAL ENTERPRISE 3 (1980).

[‡] Sidney G. Winter, *Knowledge and Competence As Strategic Assets*, *in* THE COMPETITIVE CHALLENGE: STRATEGIES FOR INDUSTRIAL INNOVATION AND RENEWAL 159, 180 (David J. Teece ed., 1987).

[1] Ronald H. Coase, *The Nature of the Firm*, 4 ECONOMICA 386 (1937); OLIVER WILLIAMSON, THE ECONOMIC INSTITUTIONS OF CAPITALISM: FIRMS, MARKETS, RELATIONAL CONTRACTING 16–18 (1985).

[2] Michael C. Jensen & William H. Meckling, *Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure*, 3 J. FIN. ECON. 305 (1976).

[3] Sanford J. Grossman & Oliver D. Hart, *The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration*, 94 J. POL. ECON. 691, 693–94 (1986); Oliver Hart & John Moore, *Property Rights and the Nature of the Firm*, 98 J. POL. ECON. 1119, 1120 (1990).

ture of the firm, because *a firm's internal governance structure is influenced by the type of knowledge required by its production process*.

Economists and management scholars have increasingly pointed to the special nature of knowledge resources as an explanation for firm boundaries.[4] According to this view, knowledge resources can explain both why firms exist, and why firms develop a particular internal structure.[5] Conversely, scholars have shown that internal corporate governance can affect knowledge management and production,[6] or put differently, that internal organizational practices can promote or inhibit the efficient use of knowledge resources within the firm.

The corporate law literature has neglected these developments. Moreover, the corporate law debate has overlooked the effects that intellectual property rights mechanisms and private contracting involving knowledge resources exert over firm internal governance structures.[7] Although recent

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[4] *See, e.g.*, ASHISH ARORA ET AL., MARKETS FOR TECHNOLOGY: THE ECONOMICS OF INNOVATION AND CORPORATE STRATEGY (2001); NICOLAI J. FOSS, STRATEGY, ECONOMIC ORGANIZATION, AND THE KNOWLEDGE ECONOMY (2005); Kathleen R. Conner & C.K. Prahalad, *A Resource-Based Theory of the Firm: Knowledge Versus Opportunism*, 7 ORG. SCI. 477 (1996); Jack A. Nickerson & Todd R. Zenger, *A Knowledge-Based Theory of the Firm: The Problem-Solving Perspective*, 15 ORG. SCI. 617, 617 (2004); Richard N. Langlois & Nicolai J. Foss, *Capabilities and Governance: The Rebirth of Production in the Theory of Economic Organization*, 52 KYKLOS 201 (1999).

[5] Some scholars have lamented the insufficiency of the traditional theories of the firm to account for production organization within the firm. *See, e.g.*, Bengt Holmström & John Roberts, *The Boundaries of the Firm Revisited*, 12 J. ECON. PERSP. 73, 90 (1998) (advocating a broader view of the firm and its boundaries: "[I]t is surprising that the leading economic theories of firm boundaries have paid almost no attention to the role of organizational knowledge."); *see also id.* at 75 (suggesting that "ownership patterns are responsive to, among other things, agency problems, concerns for common assets, *difficulties in transferring knowledge*, and the benefits of market monitoring" (emphasis added)); Harold Demsetz, *The Theory of the Firm Revisited* [hereinafter Demsetz, *The Theory of the Firm Revisited*], *in* THE NATURE OF THE FIRM 159 (Oliver E. Williamson & Sidney G. Winter eds., 1993).

[6] ALFRED D. CHANDLER, JR., INVENTING THE ELECTRONIC CENTURY 85–86 (2001). For example, Chandler attributes the failure of Remington Rand in the computer business to its "fail[ure] to build an integrated learning base." *Id.* at 86. Hence, a problem in the management of knowledge resources led to the failure of the business.

[7] Gilson's study provides an exception, making the connection between intellectual property and corporate structure. Ronald J. Gilson, *The Legal Infrastructure of High Technology Industrial Districts*, 74 N.Y.U. L. REV. 575 (1999). Gilson analyzes the impact of legal rules on the development of high-technology industrial districts. However, he looks at the high-tech industry from an aggregate perspective, comparing trends across regions, and does not develop the consequences of knowledge resources for firm internal governance structures. *See also* Dan L. Burk, *Intellectual Property and the Firm*, 71 U. CHI. L. REV. 3, 4 (2004) (examining "whether existing intellectual property law provides for efficient allocation of intellectual property rights within firms in a manner that comports with property-based theories of the firm"). There is an increasing awareness in intellectual property and employment law literature that the regulation of knowledge resources impacts the financial and organizational structure of firms. *See* Catherine L. Fisk, *Working Knowledge: Trade Secrets, Restrictive Covenants in Employment, and the Rise of Corporate Intellectual Property, 1800–1920*, 52 HASTINGS L.J. 441 (2001); Robert P. Merges, *The Law and Economics of Employee Inventions*, 13 HARV. J.L. & TECH. 1 (1999); Robert P. Merges, *Intellectual Property Rights and the New Institutional Economics*, 53 VAND. L. REV. 1857 (2000) [hereinafter Merges, *New Institutional Economics*]; Katherine V.W. Stone, *Knowledge at Work:*

literature has pointed out the importance of human capital and capabilities for corporate governance practices,[8] missing is an attempt to explain, more generally, how knowledge requirements of the production process affect internal corporate governance in concrete and specific ways, and vice-versa.[9]

We argue that knowledge that individuals bring to bear on production affects firm organization, while firm organization affects the production of new knowledge during the course of work. Knowledge-based costs help explain both why firms exist—that is, why firms prefer internalizing production to contracting for specific goods or services in the marketplace—and why firms have a particular organizational form.[10]

The structure of the firm in a competitive environment can be viewed as a result of three imperatives: (1) a firm must produce knowledge within the firm; (2) a firm must transfer and diffuse knowledge within the firm;[11] and (3) a firm must bind knowledge to the firm, that is, prevent its transfer outside of the firm. How a firm accomplishes these goals is intricately related to its organizational structure. The organizational structure of firms varies accordingly, which variation, we imagine, is capable of being described as a complex function. The type of knowledge that is used in a firm's production process is a crucial variable in this function. We therefore propose a revision of current theories of the firm to reflect that the *type of knowledge* a firm deploys is a key element in its organization.

Different types of knowledge resources will require different corporate strategies to maximize their value. Firms can bind knowledge by means of organizational strategies and legal mechanisms. Firms build less or more

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Disputes Over Ownership of Human Capital in the Changing Workplace, 34 CONN. L. REV. 721 (2002). However, the corporate law literature has largely failed to incorporate such developments.

[8] Margaret M. Blair, *Firm-Specific Human Capital and Theories of the Firm*, *in* EMPLOYEES AND CORPORATE GOVERNANCE (Margaret M. Blair & Mark J. Roe eds., 1999); Thomas F. McInerney, *Implications of High Performance Production and Work Practices for the Theory of the Firm and Corporate Governance*, 2004 COLUM. BUS. L. REV. 135.

[9] After reviewing the economic literature on firm-specific human capital, Blair argues that the law and economics literature has fixated for too long on the relationship between shareholders and managers (the principal–agent approach) to model corporate governance. *See* Blair, *supra* note 8, at 86. However, she concludes with a very general proposal: "[A]rrangements for governing the relationships among employees, and between employees and the firm, can no longer be treated as something separate from corporate governance." *Id.* She does not explain how the corporate governance literature should take human capital into consideration.

[10] Whether or not knowledge transaction costs can be treated within the scope of post-Coasian transaction cost theories is a question that is debated in the economics literature. *See, e.g.*, Langlois & Foss, *supra* note 4, at 208–10 (distinguishing between "dynamic transaction costs" arising from limited "capabilities" and the "transaction costs usually considered in the post-Coasian literature"); Conner & Prahalad, *supra* note 4, at 477 (arguing that knowledge-based theory has independent force from an opportunism-based transaction cost approach).

[11] The extent of knowledge diffusion or knowledge sharing will of course depend on the strategy a firm adopts to maximize the use of its knowledge resources in the face of the knowledge hazards it may encounter and the legal institutional environment to which it is subject. A firm may adopt a strategy of restricting its knowledge to but a few top employees, or may want to share it as much as possible in order to provide an environment suitable to innovation.

hierarchical structures, establish particular decision-making procedures, and design specific compensation packages and incentives because they are compelled to maximize the value of their knowledge resources in highly competitive environments. We show that law affects management and production of knowledge, thereby ultimately influencing corporate structure. We explain the use of intellectual property protections, restrictive covenants, and features of compensation systems as responses to firms' need to bind knowledge. We examine which organizational mechanisms emerge to meet the objective of efficient knowledge allocation.

The paper is organized as follows. Part I discusses major economic theories of the firm and points out their shortcomings in explaining a broad range of firm production organization. Next, it introduces an alternative view of the firm proposed by knowledge theories developed by economists and management scholars.

Part II proposes a typology that distinguishes between three types of knowledge inputs used in the production process, knowledge embedded in products (K_p), in organizations (K_o), and in individuals (K_i). Next, it discusses the dynamic character of these different knowledge types.

Part III explains how legal regimes impact firm organization, showing that intellectual property, contracts, and related statutory and common law rules influence firm organization and knowledge production by permitting firms to appropriate and control the knowledge types introduced in Part II.

Part IV proposes a principle of efficient knowledge allocation according to which firms will try to maximize the use of knowledge resources in the coordination of their activities. It discusses how decision-making is allocated in firm organization. A firm will develop centralized or flatter organizational hierarchies in order to apply efficiently the knowledge type that predominates in its production process. Part IV also discusses costs that stem from specific knowledge hazards.

Part V applies the theoretical framework set forth by showing how different organizational structures rely on different types of knowledge resources. Focusing on mass production, high-tech and law firms, as well as certain business transactions, such as mergers, joint ventures and licensing, we explain internal governance features in such organizations as responses to necessities of efficient knowledge allocation and management.

We show how the management of knowledge resources required in mass production and high-tech firms differentially affects their decisional hierarchies, and in certain instances also their compensation and ownership structure. We show how the change from the C-form (centralized) mass production corporation to the M-form (multidivisional) corporation has been largely driven by changes in knowledge requirements applied in the production process. We show how intellectual property rights and contract law can help shape firm internal organization by discussing a comparative case study of Silicon Valley and Boston's Route 128. We argue that particular features of employee compensation plans in high-tech firms—

namely broad-based stock options grants to non-executive employees—are justified as tools for retaining knowledgeable employees. We also investigate the changing structure of law firms, noting the increasing number of legal professionals that are ineligible for equity partnership. We discuss how the transformation of knowledge in the form of information and precedents systems during the last thirty years can account for this trend, causing law firms to expand their decisional hierarchies. We discuss how standard compensation mechanisms in law firms—the sharing model—serves to maximize efficient knowledge allocation in these firms. Finally, we investigate how certain business transactions like mergers, joint ventures and licensing contracts are shaped by knowledge inputs. We present a hypothesis concerning when such transactions will occur through market mechanisms as opposed to joint production depending on which types of knowledge resources are most important to product development.

I. THEORY OF THE FIRM

The following discussion examines some of the most important economic theories on firm boundaries and organizational structure, namely the neoclassical theory, the Coasian theory, the agency cost theory, and the property rights theory. In order to understand the contributions of the knowledge-based theory of the firm, we revisit some of the basic assumptions of these traditional theories and show how they fail to account for the influence of knowledge inputs.

A. Traditional Theories of the Firm

1. The Neoclassical Theory of the Firm.—Neoclassical theory characterizes firms by technological transformations. Firms are, in a sense, repositories for productive knowledge. Orthodoxy does not, however, engage in detailed inquiry as to the role of knowledge in the firm's organization. Sidney Winter has pointed out this shortcoming of orthodox economics:

> By taking production sets or functions as given, [textbook orthodoxy] fails to provide a framework for explaining why society's capabilities should be packaged at a particular time in one particular way and not some other way. By treating the storage of productive knowledge as costless—the analogue in this context of the assumption of costless and perfect contracts—it forecloses to economic analysis the performance of the very role that it claims is central.[12]

Neoclassical theory assumes that all firms have the same knowledge, know-how or capacity to produce, and have the same production function in the long-run. This is a serious flaw in the theory, because as Winter sug-

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[12] Sidney G. Winter, *On Coase, Competence, and the Corporation* [hereinafter Winter, *Competence*], *in* THE NATURE OF THE FIRM, *supra* note 5, at 179, 185.

gests capabilities and organizational knowledge may vary even among firms that produce in the same industry and rely on similar technologies.[13]

2. The Transaction Cost Theory of the Firm.—In *The Nature of the Firm*, Coase proposed an explanation of the existence of the firm and its boundaries based on transaction costs. The theory was groundbreaking, and it remains an extremely compelling account of governance structures in the form it has assumed through the work of Williamson.[14] Coase, however, subscribes to an account of the employment relationship that obscures the effects of knowledge resources on firm structure and boundaries.

Coase noted that the distinguishing feature of the firm is the allocation of resources by the entrepreneur, rather than the price mechanism. Moreover, Coase argued that production takes place in the firm whenever transaction costs involved in production are lower than the transaction costs for that same production on the market. For example, in order to produce a coat on the market, one would have to seek out and contract separately with a tailor, a cloth supplier, a supplier of buttons, perhaps a furrier, and so forth. Each transaction involves transaction costs from contracting in the form of information costs, negotiating costs, monitoring and enforcement mechanisms. By vertically integrating these activities, a firm can economize on transaction costs and produce more efficiently. While contracts are not eliminated within the firm, the authority of the entrepreneur greatly reduces them.[15]

Central to Coase's explanation of the firm is an understanding of the employment contract as an open-ended commitment by the employee to obey the direction of the entrepreneur over the long term (within certain limits). According to Coase, the existence of the firm can be explained by reference to the transaction-cost savings associated with the employer's fiat control over the employee.[16]

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[13] *See also* Richard R. Nelson, *Production Sets, Technological Knowledge, and R&D: Fragile and Overworked Constructs for Analysis of Productivity Growth?*, 70 AM. ECON. REV. (PAPERS & PROC.) 62 (1980) (criticizing the economic theoretical constructs of production sets, technological knowledge, and research and development). Nelson argues that orthodoxy wrongly assumes that "technological knowledge is in the form of codified how-to-do-it knowledge" as if contained in a "blue print book" which provides sufficient guidance to any firm that has access to the book. *See id.* at 63. However, "[t]here is no logical reason why the book of blueprints should be available and known to all, contained as it were, in a public library." *Id.* Furthermore, each firm will learn largely on its own, in an inimitable way, according to its particular organizational features and human capital.

[14] *See generally* WILLIAMSON, *supra* note 1, at 41–42 (developing the transaction cost paradigm by analyzing asset specificity in contractual models).

[15] *See* Coase, *supra* note 1, at 390–91.

[16] *See id.* at 403–04 ("We can best approach the question of what constitutes a firm in practice by considering the legal relationship normally called that of 'master and servant' or 'employer and employee' . . . . [I]t is the fact of *direction* which is the essence of the legal concept of 'employer and employee.'" (emphasis added)).

Coase's explanation, however, relies on a very narrow understanding of firm organization—one that assumes the entrepreneur exercises fiat control. Coase uncritically adopts this view of firm hierarchy by generalizing from nineteenth century conceptions of the relation between employer and employee.[17] Coase thereby fails to appreciate the fundamental shift between the nineteenth and twentieth century organization of production in firms, namely the emergence of a new class of salaried managers, acting both as employees (i.e. non-owners) and decision-makers.[18]

History shows that while hierarchy was crucial to the rise of the modern industrial enterprise, *entrepreneurs (owners) did not exercise fiat control over their most important employees*. In production, marketing and distribution, managers at the emerging large corporations became specialized in production processes and administration techniques, and were afforded significant decision-making authority as a result of their specialized knowledge.[19]

What is striking about the emergence of this new institutional form, as Chandler's widely accepted account of the managerial revolution describes, is the significant discretion that was given to *salaried* managers in coordinating production within the firm. The salaried managers received considerable discretion, because of their technical knowledge and their training in the coordination of production, which enabled them to make decisions as opposed to merely following orders. Coase's theory that the fiat relationship between employer and employee was *the key organizational feature* of the firm therefore does not square well with the historical evidence.

It is true that rigid hierarchical relations frequently and necessarily existed between employees at lower levels of the firm's hierarchy. More careful analysis, however, shows that the firms in which rigid, top-down authority became the defining feature of the employment relationship en-

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[17] *Id*. (citation omitted).

[18] *See generally* ALFRED J. CHANDLER, SCALE AND SCOPE: THE DYNAMICS OF INDUSTRIAL CAPITALISM (6th ed. 2001) (analyzing history of the rise of modern corporations). According to Alfred Chandler, the new type of business enterprise brought about the separation of ownership from management: "The enlarged enterprises came to be operated by teams of salaried managers who had little or no equity in the firm." *Id.* at 1. These salaried managers were employees, usually with engineering degrees, hired largely by the families who owned and ran large firms to exert control over a firm's organization and coordination of production. *Id*. at 491–92.

[19] *Id.* at 598 ("In production the new middle managers—both line and staff—had to learn intimately the technology of the products made and the processes used in the different factories under their control. So, too, in marketing and distribution middle managers had to come to know the similarities, differences, vagaries, and opportunities of different regional markets. In both production and distribution the line managers had to recruit, train, and motivate their own staffs as well as the lower-level managers under their command—the managers of plants, branch sales and purchasing offices, and laboratories. And even more than these lower-level executives, the middle managers had to learn to administer; that is, they had to learn to coordinate, to evaluate and act on such evaluations, in addition to recruiting, training, and motivating subordinates. For top managers such administrative duties were paramount. They not only had to learn to coordinate and monitor the activities of the functional departments but also to plan, allocate resources for, and implement long-term programs . . . .").

gaged in certain types of production. The paradigmatic example of a firm characterized by such authority relations is the Taylorist manufacturing firm that spearheaded assembly-line mass production.[20] Such fiat relations in firm hierarchy, however, hardly occur in the context of other types of firm organization. Take, for example, high-tech firms. High-tech firms are characterized by shared decision-making among highly specialized employees, who exercise considerable control over their work agendas and project development.[21] Indeed, high-tech firms depend upon employees exercising significant discretion in their work.[22] Coase's fiat theory, therefore, does not supply a universal account of firm structure, although it may account for the organization of a particular type of firm—that engaged in the Taylorist organization of mass production.[23]

As has been pointed out by others, a further shortcoming of Coase's theory is his general account of transaction costs.[24] Coase fails to specify sufficiently the nature of the transaction costs. Any variable can thus be invoked as a determinant of firm boundaries, as long as it is defended as a transaction cost.[25] In order to explain firm boundaries and organization,

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[20] Taylor's science of production conceived of employees essentially as machines. In firms that adhered to Frederick Taylor's principles, production was entirely restructured by the decomposition of the production process into isolatable, repetitive motions. *See* FREDERICK WINSLOW TAYLOR, THE PRINCIPLES OF SCIENTIFIC MANAGEMENT (1916). Taylorism involved a process of embedding knowledge in the production technology. It is this type of production, in which employees are treated like replaceable assets, that displays authority relations most resembling those that Coase describes. Indeed, the very purpose of Taylorism was to eliminate the entrepreneur's reliance on the judgment of his employees concerning every aspect of the production process, including the movement of their own bodies. *See also* Richard Adelstein, *Knowledge and Power in the Mechanical Firm: Planning for Profit in Austrian Perspective*, 18 REV. OF AUSTRIAN ECON. 55, 75 (2005).

[21] *See, e.g.*, Nicolai J. Foss, *Coase vs Hayek: Economic Organization in the Knowledge Economy*, 9 INT'L J. ECON. BUS. 9, 12 (2002) (noting that "a consensus seems to be emerging that tasks and activities in the knowledge economy need to be coordinated in a manner that is very different from the management of traditional industrial manufacturing activities, with profound transforming implications for the authority relation and the internal organization and boundaries of firms").

[22] Ranft and Lord find that granting autonomy and relative status to the management and employees of acquired high-tech firm's enhanced retention of key employees, but that economic incentives did not. Annette L. Ranft & Michael D. Lord, *Acquiring New Knowledge: The Role of Retaining Human Capital in Acquisitions of High-Tech Firms*, 11 J. HIGH TECH. MGMT. RES. 295 (2000).

[23] Even firms that organized their production according to Taylor's principles, however, were only partially characterized by fiat relations of authority. As already described, at the level of managerial employees such firms depended on expanding the discretion of non-owners.

[24] *See, e.g.*, Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 164 (arguing that the lack of specification of what are transaction costs "deprives transaction cost theory of any predictive content").

[25] Coase himself has admitted that his theory is too general to provide specific applications. *See* Ronald H. Coase, *The Nature of the Firm: Meaning*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 48, 73 ("[I]in that article [*The Nature of the Firm*] I emphasized the comparison of the costs of transacting with the cost of organizing and did not investigate the factors that would make the costs of organizing lower for some firms than for others. This was quite satisfactory if the main purpose was, as mine was, to explain why there are firms. *But if one is to explain the institutional structure of production in the*

however, one must identify the most relevant types of transaction costs. Accordingly, this Article argues that the cost of coordinating knowledge turns out to be a significant transaction cost that affects firm boundaries and structure.

The difficulty of coordinating a large number of different bodies of knowledge imposes limits on firm size. Each firm has command of specific knowledge sets that it deploys in its production process. For a firm that produces food products to engage in activities in the pharmaceutical industry would be inefficient, as this would require marshalling entirely different knowledge sets, i.e., those appropriate to developing chemical products and drugs. For this reason, firms tend to expand the scope of their activities to fields in which their accumulated knowledge can afford a competitive advantage.[26] Even if all other transaction costs that Coase sets forth were zero, not all production would be carried out exclusively in the market[27] or exclusively by one big firm.[28] The cost associated with possessing and coordinating the relevant knowledge for organizing every type of transaction within the firm would be prohibitive.

Knowledge costs are, therefore, an important determinant of firm boundaries and must be studied separately. They cannot simply be subsumed within the general concept of transaction costs advanced by Coase.[29]

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system as a whole it is necessary to uncover the reasons why the cost of organizing particular activities differs among firms." (emphasis added)).

[26] *See* Winter, *Competence*, *supra* note 5, at 179, 190–91 ("Of course, when a firm grows by vertical integration, it is not just a question of 'more of the same.' But it is more of something closely related, something about which the firm already has some degree of relevant knowledge.").

[27] Transaction-cost economics tends to argue that if transaction costs are zero, there is no firm as a collective entity. This is because it is assumed that each individual will act as a firm. However, Demsetz already highlighted the weakness of that argument:

> [T]he inference . . . that all production is individualized if transaction cost is zero, is wrong. . . . Multiperson firms are fully consistent with zero transaction cost if management is subject to scale economies. Zero transaction cost informs us only that these cooperating efforts will be organized with greater reliance on explicit negotiations than would be true if transaction costs were positive. . . . [T]he substance of the firm is reflected in the style of cooperative behavior that obtains.

Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 163. We argue that knowledge gained through the coordination process within the firm will make production within the firm efficient even if transaction costs are zero.

[28] *See* Coase, *supra* note 1, at 394 ("Why is not all production carried on by one firm?"); *see also* Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 173 ("The process of further product refinement is halted when the next version of the product will be put to . . . multiple uses downstream that rely on different bodies of knowledge. A single firm if it was vertically integrated would have difficulty acquiring and maintaining the stocks of knowledge necessary to control cost and quality and to make good managerial decisions when downstream uses are multiple in this sense . . . . Roughly speaking . . . *the vertical boundaries of a firm are determined by the economics of conservation of expenditures on knowledge*." (emphasis added)).

[29] One can find passages where Coase implicitly admits the importance of knowledge for determining firm boundaries:

> Apart from variations in the supply price of factors of production to firms of different sizes, it would appear that the costs of organizing and the losses through mistakes will increase with an increase in the spatial distribution of the transactions organized, in the dissimilarity of the transac-

3. Nexus of Contracts and Agency Cost.—Jensen and Meckling treat the firm as a nexus of contracts subject to agency costs. The firm is viewed as a

> nexus of a set of contracting relationships . . . mak[ing] clear that the . . . firm is not an individual . . . [but] is a legal fiction which serves as a focus for a complex process in which the conflicting objectives of individuals (some of whom may "represent" other organizations) are brought into equilibrium within a framework of contractual relations.[30]

Agency costs are the result of a conflict between the agent's self-interest and the interests of the principal. Monitoring is necessary to limit the agent's pursuit of her own interest to the detriment of the principal's interest. As such, monitoring costs count as agency costs. Similarly, the agent incurs costs that arise solely from the inability of the principal to fully control the agent. The agent must bond herself in order for the principal to entrust her with her interests. Thus monitoring, bonding, and residual costs are defined as agency costs and are used by Jensen and Meckling to explain the organizational structure of the firm.[31]

The agency cost framework suggests that the greater the "gap" between the agent and the principal, the greater the agency costs. Greater autonomy for groups or individuals within an organization, on this logic, results in increased agency costs—all else being equal. If containing agency costs is viewed as the most important feature of successful business organization, then a prescription appears to follow: Concentrate decision-making authority in the hands of as few agents as possible, who are closely monitored and directed by the principals.[32]

> tions, and in the probability of changes in the relevant prices. As more transactions are organized by an entrepreneur, it would appear that the transactions would tend to be either different in kind or in different places. . . . All changes which improve managerial technique will tend to increase the size of the firm.

Coase, *supra* note 1, 397 (citations omitted). Coase realized that inventions will not always increase the size of a firm. *Id.* at 397 n.3. Giving the example of the telephone, Coase argues that "if [it] reduces the costs of using the price mechanism [market], more than it reduces the cost of organizing [production in the firm]," then it will make firms smaller. *Id.* In our view, this result reflects a knowledge economizing strategy. For example, a firm does not need to build a telephone if it wants to use one. Producing telephones, if a firm does not already have the knowledge or capabilities to do so, would raise its organization costs disproportionately. The firm can buy the telephone in the market. *See also* Ronald H. Coase, *The Nature of the Firm: Origin*, 4 J.L. ECON. & ORG. 3, 11 (1988) ("There may be technical advantages in increasing complexity *but it is decreasing returns to managerial ability which seems to set the limit*." (emphasis added)).

[30] Jensen & Meckling, *supra* note 2, at 311. It is important to note that by focusing on agency costs, Jensen and Meckling actually do not, in fact, explain why firms exist. Instead, they analyze how firms constrain agency costs, making production within the firm possible, and they explain some aspects of the financial structure of firms. *Id.* at 305–06.

[31] *Id.* at 308–10.

[32] This is not necessarily what agency-cost theory posits, but note that this is the logic behind some current proposals for strengthening shareholder power, that is, containing agency costs by giving the

Recent developments in management, however, challenge this conclusion. Contemporary CEOs and management theorists champion the value of decentralized decision-making.[33] "Traditional industrial corporations concentrated power in top management," writes one such theorist, "yet many of the most successful corporations in recent years have implemented radical changes in governance systems."[34] These changes attempt to capture the gains of localism. The core dilemma, is "how to gain the advantages of local autonomy and decision making while increasing the ability to understand and manage interdependence."[35]

Shell Oil, for example, engaged in an abrupt, full-scale shift from centralized to decentralized governance beginning in 1994. It "chose a federalist governance model" in which "[p]ower was held as much as possible by independent entities with profit-and-loss accountability."[36] The separate entities would still have interaction and responsibility to one another and to the center, but they had their own capital structures and internal debt levels, and could make their own investment decisions. Shell created internal boards of directors for advice and oversight and for sharing ideas. These boards were linked through interlocking membership. Further structures were put into place to ensure business alignment and overarching mission. In this way, Shell Oil "moved away from the controlling corporate center, and pushed decision making lower in the organization."[37]

Such an approach does not square well with traditional proposals that rely on agency-cost theory. How can a firm contain its agency costs by devolving decision-making authority down onto an increasing number of agents with local autonomy? Would this not raise agency costs? Would opportunism not increase? The most plausible explanation presented by agency-cost theorists for whatever success such organizational structures find centers around a cost–benefit argument. If the benefits of such a de-

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principals more power to make business decisions. Lucian A. Bebchuk, *The Case for Increasing Shareholder Power*, 118 HARV. L. REV. 833 (2005).

[33] *See, e.g.*, THOMAS W. MALONE, THE FUTURE OF WORK: HOW THE NEW ORDER OF BUSINESS WILL SHAPE YOUR ORGANIZATION, YOUR MANAGEMENT STYLE, AND YOUR LIFE 3–4 (2004) (advocating benefits of decentralization in business organization); PETER M. SENGE, THE FIFTH DISCIPLINE: THE ART AND PRACTICE OF THE LEARNING ORGANIZATION 287–302 (19th ed. 1994) (setting forth the benefits of "localness" as a decision principle for knowledge intensive organizations); *see also* THE DANCE OF CHANGE: THE CHALLENGES OF SUSTAINING MOMENTUM IN LEARNING ORGANIZATIONS (Peter Senge et al. eds., 1999) [hereinafter THE DANCE]; Jan Zabojnik, *Centralized and Decentralized Decision Making in Organizations*, 20 J. LAB. ECON. 1 (2002). In the law, Michael Dorf and Charles Sabel draw on management literature to advocate decentralization in governmental organization. Michael Dorf & Charles Sabel, *A Constitution of Democratic Experimentalism*, 98 COLUM. L. REV. 267, 292–314 (1998); *see also* William W. Buzbee, *Recognizing the Regulatory Commons*, 89 IOWA L. REV. 1, 59–60 nn.227–32 (2003) (citing managerial literature).

[34] *Governance: The Challenge*, *in* THE DANCE, *supra* note 33, at 361.

[35] *Id.* at 363.

[36] *Id.* at 385. *But see Shell Structure Has to Change, Investor Says*, N.Y. TIMES, Feb. 9, 2004, at C3 (reporting that investors called for greater centralization of Shell's organizational hierarchy).

[37] THE DANCE, *supra* note 33, at 384.

centralized organization outweigh the resulting agency costs, the outcome will still be desirable. But such an answer begs the question why decentralization encompasses such benefits.

Agency cost theory does not provide a sufficient theoretical framework to explain why granting agents greater autonomy is successful without a proportional increase in ratification and monitoring mechanisms.[38] Greater dispersion of decision-making authority within firms is clearly a result of the increasing knowledge intensity of productive activity, forcing companies that want to remain competitive to make use of their human capital at every level of the company hierarchy. This movement away from traditional hierarchical governance structures cannot be fully understood without reference to a knowledge-based theory of the firm.

4. Property Rights Theory.—Property rights theory explains firm boundaries based on the ownership of physical assets. A firm "consist[s] of those assets that it owns, or over which it has control."[39] Property rights theory, therefore, does not distinguish between ownership and control, but defines ownership as the capacity to exercise control. Control is thus achieved through the ownership of physical assets.

Property rights theory derives its appeal from its elegant mathematical formalizations that shed light on certain types of firm structure. Hart and Grossman's theory may be most useful in explaining the structure of mass production systems, and specifically those engaged in Taylorist production, as in such firms the physical ownership of machines is paramount while employees are replaceable. But this circumstance is peculiar to a type of production that embeds knowledge in the production process, or, more specifically, in machines.

The theory assumes that ownership gives the owner all rights to dispose of physical assets that the owner has not given away, or that the government has not taken by force. The theory, however, ignores the reality

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[38] Eugene Fama & Michael C. Jensen, *Separation of Ownership and Control*, 26 J. LAW & ECON. 301, 301–02 (1983). In trying to explain the survival of organizations in which agents make important decisions but do not bear a significant share of the wealth effects of such decisions, Fama and Jensen state:

> We contend that separation of decision and risk-bearing functions survives in these organizations in part because of the benefits of specialization of management and risk bearing but also because of an effective common approach to controlling agency problems caused by separation of decision and risk-bearing functions. In particular, our hypothesis is that the contract structures of all these organizations separate the ratification and monitoring of decisions from initiation and implementation of the decisions.

Id. Nonetheless, when we nowadays observe the trend towards decentralization in some organizations it is not clear that the process of separation between initiation and ratification occurs at all levels at which important business decisions are taken. In many instances, agents may have enough power so as to initiate, implement, and ratify decisions which will not even reach, for example, the board of directors, which is the organ to which Fama and Jensen attribute the ratification and monitoring authority. *See id.* at 323.

[39] Grossman & Hart, *supra* note 3, at 693.

that ownership does not necessarily afford the power to control the property. This is clear in corporate law, in that the shareholders own the corporation, but do not have the legal right to control its everyday business decisions. The average shareholder also never gave away such a right. Moreover, even if the shareholder wanted to retain the right to make everyday decisions, or ask that it be returned to him, he would not be so entitled under corporate law.[40] Ownership, therefore, does not always provide the right to exercise control.

Hart and Grossman define the firm "as being composed of the assets (e.g., machines, inventories) that it owns."[41] By focusing solely on physical assets, however, they fail to recognize that in many situations physical assets cannot be used independently of expertise. In the pharmaceutical or chemical industries, physical assets can play a significant role, but if a company does not have the knowledge capabilities to make use of these assets, any investment in their purchase is irrational.[42]

In his later work, Hart has argued that the property rights approach can explain how the purchase of physical assets will allow for control over human assets.[43] He defends the position that a worker will better pursue the objectives of a principal if that principal is the worker's boss. The reason for this, according to Hart, is that the boss controls the assets the worker uses. Hart believes the logic underlying his result is different from the Coasian explanation: Coase thinks a boss can tell a worker what to do, while Hart argues that it is in the worker's self-interest to obey his boss, because this will put the worker in a better bargaining position with his boss later on. "[T]he employer can deprive the employee of the assets he works with and hire another worker with these assets."[44]

We believe property rights theory has serious shortcomings. There are many cases where the employees themselves are the most important assets for firm production. If employees are the most important assets, as for ex-

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[40] Hart has admitted that the property rights approach cannot account for the separation of ownership and control in large publicly held corporations. Oliver Hart, *An Economist's Perspective on the Theory of the Firm*, 89 COLUM. L. REV. 1757, 1173 (1989).

[41] Grossman & Hart, *supra note* 3, at 692.

[42] Assume that an entrepreneur owns a chemical laboratory. What is the purpose of owning such a physical asset without the knowledge required to develop chemicals and thereby extract value from these assets?

[43] Hart, *supra* note 40, at 1170–1171.

[44] *Id.* at 1771; *see also* Hart & Moore, *supra* note 3, at 1150; Oliver D. Hart, *Incomplete Contracts and the Theory of the Firm*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 138, 151 ("Authority and residual rights of control are very close and there is no reason why our analysis of the costs and benefits of allocating residual rights of control could not be extended to cover human, as well as physical, assets. . . . In particular, an important difference between an employment contract and a contract between independent parties is that the former allows the employer to retain the use of assets used by the employee in the event of a separation (he can hire another employee to operate them). In contrast, an independent contractor would typically own some of these assets and would be able to decide how they should be used if the relationship terminates.").

ample in law firms or high-tech firms, the physical assets are largely irrelevant to control. If the employee leaves, he takes the main asset required for the development of a firm's products or services—his knowledge—with him.[45] Property rights theory is therefore incomplete, because it can only explain the relationship between the employer and the employee in a Taylorist firm.

B. The Knowledge-Based Theory of the Firm

In the previous section we examined gaps in traditional theories of the firm concerning their ability to account for production that relies extensively on human capital. Proponents of the knowledge-based theory of the firm point out that the literature has unreflectively relied on a dichotomy between production costs and exchange costs.[46] In analyzing exchange costs, the literature recognizes that exchange itself is not costless, but involves transaction costs stemming from imperfect information and opportunism. But in analyzing production costs, there has been an implicit assumption that price theory tells us all we need to know about production. However, it is very likely that both knowledge about how to produce and knowledge about how to link together one person's (or organization's) productive knowledge with that of another are imperfect.[47] These issues of capabilities and coordination are distinct from the hazards of contracting that traditional theories have focused on. But these costs of production have been, until recently, largely neglected.[48]

Both knowledge resources and production costs differ depending on the attributes of a production process, in the same way that transaction costs differ depending on the asset and exchange attributes of investment projects.[49] Transaction cost economics hold knowledge costs constant across alternative modes of organization as a useful strategy for explicating, for example, the influence of transaction costs on the decision to integrate, or on monitoring structures and control. We suggest holding transaction costs

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[45] We refer here to situations where there are no intellectual property or related common law protections that could bind the knowledge to the firm.

[46] Langlois & Foss, *supra* note 4, at 5.

[47] *Id.* at 6–7.

[48] As Demsetz states:

> Economic organization, including the firm, must reflect the fact that knowledge is costly to produce, maintain, and use. In all these respects there are economies to be achieved through specialization. . . . [W]e generally identify industries, and firms in these industries, as repositories of specialized knowledge and of the specialized inputs required to put this knowledge to work. Steel firms specialize in different stocks of knowledge and equipment than do firms in investment banking or industrial chemicals, and even firms in the same industry differ somewhat in the knowledge and equipment upon which they rely.

Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 171–72.

[49] *See, e.g.*, Oliver E. Williamson, *The Logic of Economic Organization*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 90, 97.

constant as a strategy to assess the differential impact of knowledge costs on firm organization.[50]

There has been an increasing demand for education and skill since the mid-twentieth century.[51] With the rise of the knowledge economy, organizational structures and relations of production have undergone significant changes. Scholars have been discussing the shift of economic paradigms from scale-based competition to knowledge-based competition.[52]

The financial structure of "knowledge companies," moreover, appears to differ dramatically from the financial structure of more traditional industrial companies. Microsoft and IBM provide an interesting example. IBM, "the talismanic corporation of the fifties, sixties, and seventies,"[53] had sales more than fifteen times greater than those of Microsoft at the beginning of 1996, and its fixed assets (net of depreciation) were $16.6 billion worth of

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[50] Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 174 ("Two firms facing the same labor transaction costs may choose different employment arrangements because the benefits they derive from these arrangements differ. *Particularly important in determining these benefits are knowledge-based considerations.* Continuing association of the same persons makes it easier for firm-specific and person-specific information to be accumulated (see the large literature on specificity of human capital). Knowledge about the objectives and organization of the firm is learned 'cheaply' through continuing association, and so is knowledge about the capabilities and limitations of the persons involved in this association." (emphasis added)).

[51] Kevin M. Murphy & Finis Welch, *Occupational Change and Demand for Skill, 1940–1990*, 83 AM. ECON. REV. 122 (1993) (arguing that there was a huge increase in the demand for skill and education between 1940 and 1990); *see also* Chinhui Juhn et al., *Wage Inequality and the Rise in Returns to Skill*, 101 J. POL. ECON. 410 (1993) (finding a consistent increase in wage inequality favoring the most skilled workers).

[52] Alfred D. Chandler, Jr., & Takashi Hikino, *The Large Industrial Enterprise and the Dynamics of Modern Economic Growth*, *in* ALFRED D. CHANDLER, JR., FRANCO AMATORI & TAKASHI HIKINO, BIG BUSINESS AND THE WEALTH OF NATIONS 33 (Alfred D. Chandler, Jr. et al. eds., 1997). We do not provide an exhaustive bibliography of scholarly work that has addressed the special features of the knowledge economy, but some of the important references include: FRITZ MACHLUP, 1 KNOWLEDGE, ITS CREATION, DISTRIBUTION, AND ECONOMIC SIGNIFICANCE: KNOWLEDGE AND KNOWLEDGE PRODUCTION (1980); FRITZ MACHLUP, 2 KNOWLEDGE, ITS CREATION, DISTRIBUTION, AND ECONOMIC SIGNIFICANCE: THE BRANCHES OF LEARNING (1982); FRITZ MACHLUP, 3 KNOWLEDGE, ITS CREATION, DISTRIBUTION, AND ECONOMIC SIGNIFICANCE: THE ECONOMICS OF INFORMATION AND HUMAN CAPITAL (1984); THOMAS STEWART, INTELLECTUAL CAPITAL (1984); THOMAS A. STEWART, INTELLECTUAL CAPITAL: THE NEW WEALTH OF ORGANIZATIONS (1997) [hereinafter STEWART, NEW WEALTH]; Joseph E. Stiglitz, Public Policy for a Knowledge Economy 3 (1999), http://www.worldbank.org/html/extdr/extme/knowledge-economy.pdf ("[T]he movement to a knowledge economy necessitates a rethinking of economic fundamentals."); PETER F. DRUCKER, POST-CAPITALIST SOCIETY 39 (1993) ("[F]ar too few people realize that the application of knowledge to work created developed economies by setting off the productivity explosion of the last hundred years. Technologists give the credit to machines, economists to capital investment. Yet both were as plentiful in the first hundred years of the capitalist age, before 1880, as they have been since. With respect to technology or to capital, the second hundred years differed very little from the first one hundred. But there was absolutely no increase in worker productivity during the first hundred years—and consequently very little increase in worker's real incomes or any decrease in their working hours. What made the second hundred years so critically different can only be explained as the result of *applying knowledge to work.*"); THE KNOWLEDGE ECONOMY (Dale Neef ed., 1998).

[53] STEWART, NEW WEALTH, *supra* note 52, at 33.

property, plants, and equipment, with a market capitalization of about $70.7 billion. In contrast, Microsoft's net fixed assets at that time totaled just $930 million. But Microsoft's total capitalization was $85.5 billion, despite its much lower sales. As Thomas Stewart has pointed out:

> [A]n investor who acquires shares of Microsoft is not buying assets in any traditional sense; for that matter, he is not purchasing much in the way of assets if he buys IBM or Merck or General Electric. A dollar invested in a corporation buys something different from the same dollar invested in the same corporation a few years ago.[54]

In other words, in many industries ownership of physical assets has become less and less important while the significance of human resources has increased tremendously. The predominance of "intangible assets" in a firm's market value calls for a revision of traditional theories of the firm.[55]

Production in a competitive economy requires the use of different knowledge resources, both purchased on the market and produced by the firm. The particular nature of knowledge resources presents unique characteristics that provide powerful reasons for differentially structured firm production. The way a firm develops the knowledge it will use in its production process and the extent that the firm can bind this knowledge to its structure will influence its organizational structure.

The knowledge-based theory we advance distinguishes between three basic knowledge inputs. Based on different forms of knowledge applied in the production process, this theory offers a more complete explanation and fills the gaps left by the traditional theories described above. As we will explain in the next part, knowledge can be embedded in (1) physical assets such as machines, (2) in the organization itself, and (3) in individuals.

II. A KNOWLEDGE TAXONOMY

A. The Location of Productive Knowledge (K_p, K_o, K_i)

Firms depend on knowledge resources.[56] Knowledge formation within the firm is crucial to production in competitive markets. Firms that compete in mass production, however, have different knowledge requirements

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[54] *Id.*

[55] In the organizational management literature, an increasing emphasis is placed on knowledge production. Books on "the learning organization," "intellectual capital," "human capital," and "knowledge management" abound. Firms are considered repositories of productive capabilities. Langlois and Foss interpret the capabilities perspective "as reaching for a distinct theory of economic organization, one that is based on a conceptualization of the firm as a repository of productive knowledge with certain nonstandard characteristics . . . . In this story, incentive issues are suppressed in favor of a focus on problems of coordinating knowledge and expectations." Langlois & Foss, *supra* note 4, at 26.

[56] We distinguish between information and knowledge. Knowledge consists of the ability to process retained information to some end. Information can be processed into some input. This is what knowledge does. The mere knowledge of facts is likely to be information.

than firms that compete in high-technology fields.[57] To analyze how knowledge requirements affect firm structure, we distinguish between different forms that knowledge resources take using a typology of three types of knowledge structures.

We term K_p knowledge embedded in physical assets, such as machines or products. Taylorist production provides perhaps the best example of this type of knowledge structure. In assembly-line production, the knowledge required in the production process is embedded in machines. Assembly-line workers are largely unskilled and easily replaceable in this sort of production. Products also embody knowledge, allowing consumers to extract knowledge benefits without themselves having to master the knowledge. For example, most anyone can operate a computer through software that performs highly complex and labor-intensive procedures without knowing all the stages necessary to produce either the tool or the specific output the tool supplies.[58] Such machines are vehicles of "knowledge-substitution" in that they permit the application of knowledge embedded in the machine (including the knowledge necessary to build the machine), by merely using the machine. An employee performing routine work typically relies heavily on knowledge embedded in machines and other products in performing her work. In many instances, her technical expertise may be crude and limited to the ability to operate the machine.

We term K_o knowledge embedded in the organizational structure or the group of individuals that constitute the firm.[59] It consists of the habits, prac-

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[57] *See* J. Rogers Hollingsworth, *Continuities and Changes in Social Systems of Production: The Cases of Japan, Germany, and the United States*, *in* CONTEMPORARY CAPITALISM: THE EMBEDDEDNESS OF INSTITUTIONS 265, 269 (J. Rogers Hollingsworth & Robert Boyer eds., 1999) (arguing that "[f]irms that successfully employed a mass production strategy had to engage in a particular form of industrial relations, use specific types of machinery, and relate in particular ways to other firms in the manufacturing process"); Harold Demsetz, *Comments on Michael C. Jensen & William H. Meckling, Specific and General Knowledge, and Organizational Structure*, *in* CONTRACT ECONOMICS 275, 276 (Lars Werin & Hans Wijkander eds., 1992) (arguing that different types of firms rely on different types of knowledge). "Because their activities are so dissimilar, biotechnology firms, steel firms, and retail establishments, by design, inventory different stocks of knowledge. Generally, these stocks are 'housed' in the people employed." Demsetz, *supra*, at 275–276.

[58] *See* Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 159, 173 ("Because it is uneconomical to educate persons in one industry in the detailed knowledge used in another, recourse is had to developing or *encapsulating this knowledge into products or services* that can be transferred between firms cheaply because the instructions needed to use them do not require in-depth knowledge about how they are produced . . . . The economical use of industrial chemicals by steel firms does not generally require knowledge of how these chemicals are produced; similarly, the use of steel by industrial chemical firms does not require transfer of knowledge of how the steel is produced. A production process reaches the stage of yielding a saleable product when downstream users can work with, or can consume, the 'product' without themselves being knowledgeable about its production." (emphasis added)).

[59] Nelson and Winter identified this knowledge type in their evolutionary model of economic institutions. RICHARD NELSON & SIDNEY WINTER, AN EVOLUTIONARY THEORY OF ECONOMIC CHANGE (1982).

tices and routines of a firm's organizational structure and culture.[60] Generally this asset is transferable only by selling the firm or a part of it.[61] The knowledge, in this case, is embedded in a "production team" that can operate and maintain itself in the absence of the owner or any one specific member.[62] Individual employees may be replaceable because knowledge resources are dispersed across many different co-workers and individuals. In contrast to K_p, K_o is collective knowledge created through, and residing in, patterns of interaction among individuals within the organization.

We term K_i the specialized knowledge embedded in the individual. The skills of a craftsperson, an artist, or a professional athlete are paradigmatic examples of such knowledge.[63] Knowledge of this sort cannot be transferred costlessly from one person to another.[64] And often the cost of knowledge transfer between persons is very high because the relevant knowledge is based on experience and is tacit.[65] Where knowledge is tacit, relocating individuals to the site where such learning takes place may be necessary to achieve knowledge transfer.[66] Knowledge that has been formalized, standardized and is thus easily transferable generally does not qualify as K_i. The capacity of an individual to assimilate such specialized knowledge due to formal or other education is considered K_i.

Note that the bright-line categories we have created here are fluid and can blur in reality. Knowledge of the K_o and K_i types is most likely to over-

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[60] Sherwin Rosen, similarly, refers to such knowledge as knowledge vested "in the firm." Sherwin Rosen, *Learning by Experience as Joint Production*, 86 Q.J. ECON. 366, 367 (1972); *see also* Ranft & Lord, *supra* note 22, at 298 (discussing the acquisition of knowledge sets that are "embedded in relationships among individuals, or in a firm's more general social and organizational fabric, rather than in any particular person").

[61] There is, of course, an overlap between knowledge embedded in the individual employee and knowledge embedded in the organizational structure. *See* Ranft & Lord, *supra* note 22, at 298 ("[A] firm's valuable knowledge-based resources may reside not only in particular individuals, but also in socially complex relationships among different individuals and organizational subunits . . . . In the case of socially complex knowledge, no single person has the full set of skills and capabilities required to create a commercially viable product or service." (citations omitted)).

[62] Rosen, *supra* note 60, at 367. In the corporate law literature, see Margaret M. Blair and Lynn A. Stout, *A Team Production Theory of Corporate Law*, 85 VA. L. REV. 247 (1999).

[63] Individuals accumulate such knowledge "of the particular circumstances of time and place" through personal experience in the Hayekian sense. F.A. Hayek, *The Use of Knowledge in Society*, 35 AM. ECON. REV. 519, 521–26 (1945).

[64] Rosen, *supra* note 60, at 367. Rosen, for example, refers to "*knowledge completely vested in the owners* (or managers) of the firm." *Id.* (emphasis added). As he explains, this "knowledge may be identified with pure 'entrepreneurship' . . . . Here the asset is not salable, though the owners may rent the services of their knowledge elsewhere." *Id.* This is what we mean by K_i—that the knowledge is embedded in the individual, whether she be the owner of the firm, a manager, or an employee.

[65] See MICHAEL POLANYI, THE TACIT DIMENSION (1966). We discuss the definition of tacit knowledge *infra* Part II.B.

[66] Gilson, *supra* note 7, at 595 ("This [tacit] element of the employer's intellectual property is embedded in the employee's human capital, and can be most effectively transferred through proximity and, in particular, by an employee changing jobs.").

lap. This occurs, for example, where the knowledge possessed by one individual is also possessed by others in a given organization. One important difference between K_i and K_o, however, is the length of time required for decision-making. K_i implies a finite horizon, as the capital will vanish when the owner of the knowledge departs (retires, or passes away). K_o implies an infinite horizon, since the knowledge can be preserved within the structure of the firm and transferred with the firm.[67] Note also that these variables are interdependent to some extent. K_o may depend on K_p, for certain routines arise in order to manage certain machines and products. K_o is not readily transferable from firm to firm. Routines that work in some environments may not work in other environments. Furthermore, K_i may vary depending on different experiences that individuals have with the same products or machines. This will be further developed in the next section.

Below we present a table that systematizes these concepts.

[67] Rosen, *supra* note 60, at 368.

Table A: Knowledge Types

	KNOWLEDGE TYPE		
	K_p	**K_o**	**K_i**
General Description	Knowledge Embedded in Machines and Products	Knowledge Embedded in a Firm's Organizational Structure (Not Codified)	Specialized or Technical Knowledge and Skills Embedded in Individuals
Examples	Codified Production Processes and Technology Machines and Tools Technological Devices Legal Opinions Computer Software	Structuring of Decision-Making Processes Organizational Routines and Business Methods Coordination and Division of Work Knowledge Management Practices Monitoring Structures Quality Control Procedures	Scientific Training Professional Training Craft and Skill Acquaintance with Professional Networks Personal Experience Knowledge Concerning a Firm's Suppliers, Customers, or Markets Knowledge of Organizational Routines and Business Practices

Source: Authors' elaboration.

B. Tacit Versus Standardized Knowledge

In the development of this taxonomy, and throughout this Article, we make reference to a crucial dimension of knowledge inputs: the degree to which knowledge has been articulated, codified, or standardized on the one hand, and the degree to which it is *tacit* or unarticulated, uncodified, or un-standardized on the other. The distinction has been put in different ways. A prime example of tacit knowledge is an individual skill, such as a local pilot's ability to safely bring a ship into the harbor and to its berth:

> What the pilot knows are local tides and currents along the coast and estuaries, the unique features of local wind and wave patterns, shifting sandbars, unmarked reefs, seasonal changes in microcurrents, local traffic conditions, the daily vagaries of wind patterns off headlands and along straits, how to pilot in these waters at night, not to mention how to bring many different ships safely to berth under variable conditions.[68]

This "know-how" supercedes the general rules of navigation and cannot be codified or standardized, but depends upon sense and long experience working within a particular local context.

The point for our purposes is that individual knowledge, or K_i, is often highly tacit in the sense that "the aim of a skillful performance is achieved by the observance of a set of rules which are not known as such to the person following them."[69] While all codified knowledge originated with tacit knowledge (witness Pythagoras' contemplation of geometric figures drawn in the sand), some types of knowledge remain hard, or even impossible, to articulate or codify. As Polanyi has said: "[*W*]*e can know more than we can tell*."[70] A person with tacit knowledge may not be able to provide a useful explanation of the rules that he is applying in the pursuit of his skillful activity.[71]

Once knowledge is codified, standardized, and rendered explicit, however, it is no longer embedded in the individual, but "can be communicated from its possessor to another person in symbolic form, and the recipient of the communication becomes as much 'in the know' as the originator."[72] Such knowledge may take the form of manuals, blueprints, books, etc., that permit the ready dissemination of knowledge. Knowledge embedded in products, K_p, necessarily has been standardized and rendered explicit in order to be deployed in a product.

Because codified and standardized knowledge is readily communicable, it is also much more susceptible to the public goods problems and the related opportunism that we discuss in Part IV of this Article, which, without certain external protections, may render market transactions of this sort of knowledge more costly.

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[68] JAMES SCOTT, SEEING LIKE A STATE 316–17 (1998).

[69] MICHAEL POLANYI, PERSONAL KNOWLEDGE 49 (1962).

[70] POLANYI, *supra* note 65, at 4.

[71] OLIVER E. WILLIAMSON, MARKETS AND HIERARCHIES: ANALYSIS AND ANTITRUST IMPLICATIONS 21–22 (1975) ("Language limits refer to the inability of individuals to articulate their knowledge or feelings by use of words, numbers, or graphics in ways which permit them to be understood by others. Despite their best efforts, parties may find that language fails them (possibly because they do not possess the requisite vocabulary or the necessary vocabulary has not been devised), and they resort to other means of communication instead. Demonstrations, learning by doing, and the like may be the only means of achieving understanding when such language difficulties develop.").

[72] Sidney G. Winter, *Knowledge and Competence As Strategic Assets*, *in* THE COMPETITIVE CHALLENGE: STRATEGIES FOR INDUSTRIAL INNOVATION AND RENEWAL 159, 170–71 (David J. Teece ed., 1987).

While tacit knowledge is hard to transfer and is thus less susceptible to opportunism, this does not necessarily render market transactions of tacit knowledge less complicated or costly. The very difficulty of describing tacit knowledge raises special difficulties. Tacit knowledge may not be readily transferred through an exchange, but may require context-specific learning. The non-communicable character of tacit knowledge[73] 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. The production of knowledge resources may require extensive communication and exchange of ideas and personal experience,[74] and therefore we suggest that tacit knowledge can be better shared in the structure of a firm, as opposed to the market. We develop these ideas further below.

C. The Dynamics of Productive Knowledge

The typology of knowledge structures given so far presents a static picture. Knowledge structures, however, change over time and this theory must, accordingly, incorporate such dynamics into its analysis.

Such transformations will depend, among other things, on the standardization process that knowledge deployed by organizations and individuals typically undergoes.[75] Standardization is the process through which tacit knowledge is made explicit, formalized, and then codified or instantiated in physical processes and products.[76] Standardization occurs where K_i

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[73] *See* Richard R. Nelson, *supra* note 13, at 65 ("What if whatever it is that permits a firm to operate a technique in a particular way and with particular outcomes is only in small part describable in a blueprint, or teachable by example, or purchasable in the form of a machine? Then the fact that firm A can operate a particular technique with a particular outcome does not mean that firm B or firm C can, even if firm A helps out their learning in every way it can. The presence of particular and rather special personal talents, or important organizational features, signals that the codified aspects of technique may only be a part of the story.").

[74] *See* Kenneth J. Arrow, *Classificatory Notes on the Production and Transmission of Technological Knowledge*, 59 AM. ECON. REV. (PAPERS AND PROC.) 29 (1969); *see also* C.K. Prahalad & Gary Hamel, *The Core Competence of the Corporation*, 68 HARV. BUS. REV., May–June 1990, at 79, 82 (attributing significant importance to communication in their concept of "core competence"). "Core competencies are the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies. . . . Core competence is communication, involvement, and a deep commitment to working across organizational boundaries. It involves many levels of people and all functions." *Id.*

[75] *See, e.g.*, Robin Cowan & Dominique Foray, *The Economics of Codification and the Diffusion of Knowledge*, 6 INDUS. & CORP. CHANGE 595, 604–05 (1997) (discussing the process of codification of tacit knowledge). *But see* MARYANN P. FELDMAN, THE GEOGRAPHY OF INNOVATION 53 (1994) ("Some aspects of knowledge have a tacit nature that cannot be completely codified and transferred through blueprints and instructions.").

[76] For one attempt to theorize knowledge creation dynamics in firms, see Ikujiro Nonaka et al., *Managing and Measuring Knowledge in Organizations: Three Tales of Knowledge Creating Companies*, *in* KNOWING IN FIRMS 146 (Georg von Krogh et al eds., 1998); Ikujiro Nonaka & Hirotaka Takeuchi, *A Theory of the Firm's Knowledge-Creation Dynamics*, *in* THE DYNAMIC FIRM 214 (Chandler et al.

is embedded in a newly created machine or product (K_p). In the mature stage of the industry life cycle, "most of the technical aspects of the product have become standardized, and the nature of demand is well known."[77] The focus of the industry then becomes standardized production.[78] In such circumstances, tacit knowledge becomes relatively less important to the production process and in the organization of the firm.

The transmission of tacit knowledge both within and between firms is facilitated by geographical proximity,[79] while explicit or codified knowledge renders the cost of transmitting information across geographic distances trivial.[80] One result of codification and standardization of knowledge in products (K_p) is that constraints on the production and distribution of products across large geographical areas (and internationally) are significantly reduced, enabling reproduction of this knowledge on a much greater scale. For instance, some underdeveloped nations are easily able to create a manufacturing industry, relying on the knowledge embedded within the machinery that forms the basis for production. However, R&D (research and development) centers are less frequently transferred to such nations as the tacit knowledge necessary for new product development is generally kept in the holding companies, for strategic reasons as well.

The reverse transformation may also occur. Engagement with physical assets can yield entirely new knowledge in the form of K_i that was not initially contemplated by the creator of the machine or embedded in the product.[81] Such a transformation occurs where an employee conceives of new ideas for the creation of a different type of machine or process by observing how the machine operates.[82] In other words, the employee develops ideas for new technologies, which, at this stage, will still be tacit, and thus knowledge embedded in this particular employee. K_p can thus give rise to K_i, and

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eds., 1998). Nonaka and Takeuchi focus on the effects of organizational structure on knowledge creation and try to understand the constraints (and opportunities) that the dynamics of knowledge creation present. They do not isolate standardization as a distinct process, preferring instead to talk about "externalization" (from tacit to explicit) and "combination" (from explicit to explicit). Nonaka & Takeuchi, *supra*, at 220–24.

[77] David B. Audretsch & Maryann P. Feldman, *Innovative Clusters and the Industry Life Cycle*, 11 REV. INDUS. ORG. 253, 259 (1996).

[78] Gilson, *supra* note 7, at 585.

[79] *See* Nelson & Winter, *supra* note 59, at 76–82 (describing tacit nature of skills).

[80] Robin Cowan & Dominique Foray, *The Economics of Codification and the Diffusion of Knowledge*, 6 INDUS. & CORP. CHANGE 595, 604–05 (1997).

[81] For example, the creation of a product, such as software, may educate the worker or user—slowly weaning her from reliance on help screens, aids, and by-the-book routines to a more efficient and sophisticated deployment of the tool's core functions by means of creative applications.

[82] Chandler & Hikino, *supra* note 52, at 33 (1977) ("Just as the capabilities that were learned by exploiting the physical economies of scale led to capital augmentation through improvement of processes and products, so the organizational skills developed in pursuing joint production at the manufacturing establishment level led not only to improvement in existing processes and products but also to the systematic commercialization of *new* processes and products. This is particularly true in industries in which joint production rested on the systematic exploitation of chemistry, biology or physics.").

probably to K_o, as this knowledge is spread from a single employee to others within the firm through the refinement of the firm's organizational routines.

Several types of knowledge transformation can therefore occur: (1) K_i can be transformed into K_o, when a routine or a process developed by an individual or small team can spread to the entire organization[83]; (2) K_o can give rise to K_i, when a new employee becomes familiar with, and learns organizational routines and knowledge; (3) K_i can be transformed into K_p, when knowledge becomes formalized and standardized, and thus becomes embedded in physical objects; (4) K_p can give rise to K_i, as the use of a product or a machine in the production process will give rise to improvements to the equipment itself, and problems posed by the equipment used in production will engender learning on the part of individuals who work to improve it; (5) K_p can give rise to K_o, such as when organizational knowledge is shaped by the characteristics of each machine and other physical assets required to operate an assembly line; (6) K_o can be transformed into K_p when, for example, a team operating an assembly line realizes that they can save time by developing a specific tool to aid in their work. The tool will be a form of K_p that originated from knowledge of the organizational routines of this assembly line, that is, from K_o.

The processes described demonstrate how knowledge types transform over time. They provide a stylized picture of how firms can change together with the nature of the knowledge they develop and deploy over time.[84] A typical mass production firm (mainly relying on K_p) might engage in more knowledge intensive activities as the operation of its machinery spurs research and development in order to maintain or improve its production process.[85] The level of K_i in the firm will thus rise. A high-tech firm (mainly relying on K_i) might develop a product and then engage in its mass production (mainly relying on K_p) thus eventually decreasing its reliance on K_i.[86] Our thesis contends that in both situations the change in the degree to which a firm relies on a certain type of knowledge (increased K_i in the first example and increased K_p in the second example) will give rise to a change in the *organizational structure* of the firm.

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[83] An example is the Japanese system of "just in time" inventories. Because of its efficiency, this process was soon transmitted to other organizations and became embedded in the structure of organizations. The technique of just-in-time inventories is now codified in management books, being transmuted into a "product" with the characteristics of K_p. However, the specific way in which a firm applies this technique may change from firm to firm, which characterizes a type of K_o.

[84] For discussions of the co-evolution of technology and institutions, see RICHARD R. NELSON, THE SOURCES OF ECONOMIC GROWTH 100–19 (1996).

[85] *See, e.g.*, Chandler & Hikino, *supra* note 52, at 27, 34.

[86] *See, e.g.*, our discussion of IBM, *infra* notes 265–269 and accompanying text.

III. LAW AND KNOWLEDGE MANAGEMENT

The variables discussed so far reflect the embeddedness of knowledge in things, persons and organizations. We now turn to the problem of how firms bind such knowledge. We distinguish between (1) organizational strategies and (2) legal mechanisms by which firms appropriate and control critical knowledge resources.

Examples of organizational strategies include restricting access to valuable knowledge to all but a handful of insiders who run the firm—a natural characteristic of family-owned businesses.[87] Geographically isolating the firm is another such mechanism. The DuPont company in its early years (just after 1800) affords an example. DuPont guarded "[m]ost of the economically valuable knowledge about the chemistry and manufacture of gun powder" by restricting it to "DuPont family members and their close associates."[88] Moreover, DuPont's Brandywine mills were located in a remote and self-contained enclave, which along with power and water, supplied security from unwanted visitors.[89] There are, however, drawbacks to such organizational strategies. Restricting critical knowledge to but a few members in the firm seriously limits potential firm size, innovation, and informed decision-making—stunting the competitiveness and growth potential of the organization. Similarly, isolating the company geographically is often undesirable.[90]

Other organizational strategies include structuring firm ownership so as to control the use of information and knowledge; entering into business transactions with other firms, such as mergers and acquisitions, or joint ventures; or acquiring complementary assets with which knowledge assets are bundled.[91]

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[87] *See, e.g.*, Fisk, *supra* note 7, at 468–69.

[88] *Id*. at 468–69, 489 ("[T]he DuPonts managed the company and supervised its research throughout the nineteenth century. Thus, the company's approach to employee intellectual property depended on close family control supported by informal sanctions and self-help.").

[89] *Id*. at 471. Geographical isolation was also characteristic of high-tech companies, such as Digital Computers, on Massachusetts's Route 128. *See* ANNALEE SAXENIAN, REGIONAL ADVANTAGE: CULTURE AND COMPETITION IN SILICON VALLEY AND ROUTE 128 (1996).

[90] Economists have recognized the importance of regional clusters for economic and technological development. Regional agglomeration of firms can result in significant positive externalities, such as knowledge spillover, that cause input costs to decline. Thus securing a firm's knowledge from competitors by isolating its employees is likely to be a poor strategic decision, especially in knowledge intensive industries. *See* Michael J. Enright, *Regional Clusters and Firm Strategy*, *in* THE DYNAMIC FIRM: THE ROLE OF TECHNOLOGY, STRATEGY, ORGANIZATION, AND REGIONS 315, 331 (Alfred D. Chandler et al. eds., 1998) ("Spillover of innovation from firm to firm is likely to be greater in regional clusters than among dispersed firms . . . ."); Gilson, *supra* note 7, at 582 (arguing that "knowledge as an input is subject to increasing returns as a result of geographic proximity"). *See generally* SAXENIAN, *supra* note 89 (providing comparative empirical case study of how social networks, and cultural and organizational structures generated the "regional advantage" of Silicon Valley's high-tech economy).

[91] Some of these strategies are identified by Winter, *supra* note 72, at 173–75. Such organizational strategies will be addressed in greater detail in *infra* Part V.

Legal mechanisms include intellectual property rights ("IPRs") and contracts. IPRs prevent the "tragedy of the commons" that would otherwise arise with knowledge resources. In the case described above, effective patent protections for chemical processes, trade secrets protections, or covenants not to compete could provide alternatives to the centralization, "hoarding" of organizational knowledge, and the geographical isolation of employees to avoid unauthorized transfer, or "leakage."[92] The availability of legal mechanisms for appropriating and controlling knowledge resources thereby affects a firm's organizational possibilities and choices. Without changes in the law during the early-twentieth century DuPont, for example, would not have been able to "begin systematically to resort to contracts . . . to protect its claims to employee knowledge."[93]

IPRs, however, do not protect all types of knowledge. The levels of protection vary depending on the industry and product. Moreover protection is imperfect and depends upon a variety of factors, including costs and levels of enforcement.[94] IPRs have additional drawbacks. Patents, for example, are searchable and the patented products can be reverse engineered.[95] Firms therefore sometimes forego patents as a strategy to prevent knowledge transfer. IPRs therefore may not provide the most effective protection.[96] Firms will, therefore, necessarily develop specific organizational mechanisms to address the problem of binding knowledge.

Apart from IPRs, many other legal regimes have significant but *indirect effects* on a firm's ability to appropriate and control knowledge resources. Antitrust policy is an obvious example in that antitrust rules significantly contract the use of patents and other IPRs.[97] Other examples are accounting and tax benefits for employee stock options, which were

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[92] We address "hoarding" and "leakage" in our discussion of knowledge transaction costs in Part IV.

[93] Fisk, *supra* note 7, at 470 ("The change in Du Pont company practice reflects, in microcosm, the change in the law."); *see also* Merges, *New Institutional Economics*, *supra* note 7, at 1862 (pointing out the role of IPRs in the recent trend towards "a dizzying array of organizational forms").

[94] *See* Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY 609, 615 (Nat'l Bureau of Econ. Res. ed., 1962) ("[N]o amount of legal protection can make a thoroughly appropriable commodity of something so intangible as information.").

[95] Pamela Samuelson & Suzanne Scotchmer, *The Law And Economics of Reverse Engineering*, 111 YALE L.J. 1575, 1584–85 (2002) ("The purchaser of a machine embodying a patented invention, for example, is generally free to disassemble it to study how it works under the first sale principle of patent law. In addition, a person who tries to make a patented invention to satisfy scientific curiosity may assert an experimental use defense to patent infringement."); *see also* Winter, *supra* note 91, at 173.

[96] Winter, *supra* note 72, at 159, 176–80.

[97] WARD S. BOWMAN, JR., PATENT AND ANTITRUST LAW: A LEGAL AND ECONOMIC APPRAISAL vii (1973). *See generally* WILLIAM C. HOLMES, INTELLECTUAL PROPERTY AND ANTITRUST LAW, vols. I & II (2006). Antitrust policy has also been cited as a factor which contributed to the rise of in-house R&D departments in large U.S. firms. DAVID C. MOWERY & NATHAN ROSENBERG, PATHS OF INNOVATION: TECHNOLOGICAL CHANGE IN 20TH CENTURY AMERICA 13–16, 39 (1998).

vigorously defended by high-tech firms as a critical mechanism for retaining knowledgeable employees. Legal rules and contract law governing employment agreements are also important for knowledge management. Rules of Professional Conduct, such as the ABA Model Rules' governing the confidentiality of attorney–client relations, may also serve to prevent unwanted knowledge transfer. We therefore distinguish (both tort-like and contract-based) IPRs that *directly* appropriate and control knowledge resources from other legal mechanisms that do so *indirectly*.

In the following, we discuss the co-evolution of IPRs and firm structure during the eighteenth and nineteenth centuries. We also analyze the type of knowledge (K_i, K_p, K_o) that is protected by each type of IPR.

A. The Co-Evolution of Intellectual Property Rules and Firm Organization

Organizational strategies are pursued in (constantly evolving) institutional frameworks.[98] Therefore, changes in legal institutions will necessarily influence organizational strategies. And organizations, in turn, will seek incremental changes in legal institutions in pursuing their own objectives.[99] This is the case for intellectual property rights as well.[100] We propose to connect the evolution of the U.S. intellectual property regime with the evolution of U.S. firm organization. Our purpose is to establish a relationship between the emergence of new organizational forms and the development of the modern IPR regime.[101] Significant changes in the IPR regime occurred during the late nineteenth and early twentieth centuries at the time of the emergence of the modern corporation. This suggests that changes in IPRs either served the evolving organizations that came to depend upon them or were at least perceived to serve their purposes.[102] While the efficiency of IPR regimes is a contested issue that goes beyond the scope of this paper,[103] we do contend that organizational structures would have been different but for the IPR regime that emerged.

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[98] DOUGLAS C. NORTH, INSTITUTIONS, INSTITUTIONAL CHANGE AND ECONOMIC PERFORMANCE 73 (2002).

[99] *Id.*

[100] "There is broad consensus that industry groups have unusually broad input into the drafting of IPR-related legislation." Merges, *New Institutional Economics*, *supra* note 7, at 1875.

[101] Historians and intellectual property scholars have noted this co-evolution, but corporate law scholars have neglected it. *See, e.g.*, DAVID F. NOBLE, AMERICA BY DESIGN: SCIENCE, TECHNOLOGY, AND THE RISE OF CORPORATE CAPITALISM 84–85 (1977); Catherine L. Fisk, *Removing The 'Fuel Of Interest' From The 'Fire Of Genius': Law and the Employee-Inventor, 1830–1930*, 65 U. CHI. L. REV. 1127 (1998); Merges, *New Institutional Economics*, *supra* note 7, at 1877.

[102] Public choice theory teaches us that legislative choices are frequently influenced by rent seeking interests. *See, e.g.*, Jessica Litman, *Copyright Legislation and Technological Change*, 68 OR. L. REV. 275, 277 (1989) (noting that "copyright legislation in this century has evolved from meetings among industry representatives whose avowed purpose was to draft legislation that provided for the future").

[103] *See, e.g.*, Winter, *supra* note 91, at 178.

1. The Development of IPRs.—It is increasingly recognized that the tremendous economic development experienced during the late nineteenth and early twentieth centuries was very much fueled by technological development,[104] and that the rise of modern corporations played a crucial role in that change.[105] Legal doctrine increasingly evolved to favor corporate ownership of intellectual property over ownership by the employee.[106]

Patent and copyright protections were already written into the U.S. Constitution at a time when modern firms and corporations did not exist. State default rules and employee contracts assigning ownership of patents and copyrights, however, evolved significantly during the late-nineteenth and early-twentieth centuries. Significant changes in the law occurred particularly during the 1880s and 1890s, around the time that the new emerging large corporations were beginning to be accorded greater legal independence through, inter alia, constitutional property rights, limited liability reflecting increased passivity of the shareholders, and the rise of the conception of large business corporations as "natural entities" distinct from partnerships.[107] The legal regimes governing patents and copyright thus evolved together with organizational forms.

In the early nineteenth century, employees typically owned all rights to their inventions.[108] Even those employees "hired to invent" typically retained title to their inventions.[109]

The so-called "shop right" emerged during the later part of the nineteenth century. By the late-1880s, courts began awarding firms a broad, nontransferable, royalty-free license to use employee inventions that were invented on the job, while awarding the residual rights to the employee.[110] In particular, the rationale for such a license shifted from earlier arguments

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[104] *See* NELSON, *supra* note 84, at 1 (singling out technical advance as "the key driving force behind [economic] growth"). *See generally* Chandler & Hikino, *supra* note 52, at 24–57 (arguing that the emerging large business corporations were drivers of technological change); MOWERY & ROSENBERG, *supra* note 97, at 3.

[105] *See, e.g.*, Chandler & Hikino, *supra* note 52, at 26; *see also* NELSON, *supra* note 84, at 2–3 (noting that "the development of those new technologies would not have borne economic fruit without the physical investments that put them into operation").

[106] *See* Fisk, *supra* note 7, at 441. *See also generally* Robert P. Merges, *One Hundred Years of Solicitude: Intellectual Property Law 1900–2000*, 88 CAL. L. REV. 2187 (2000) (describing "pro-corporate spirit" of patent law) [hereinafter Merges, *One Hundred Years*]; Robert P. Merges, *The Law and Economics of Employee Inventions*, 13 HARV. J.L. & TECH. 1 (1999) (discussing critics of U.S. law of employee inventions who describe historical trend toward corporate control of research as "amounting to confiscation" of employee inventions) [hereinafter Merges, *Employee Inventions*].

[107] *See generally* MORTON HORWITZ, THE TRANSFORMATION OF AMERICAN LAW, 1870–1960, at 65–107 (1992) (describing the transformation of the law of corporations).

[108] Fisk, *supra* note 101, at 1129.

[109] *See id.* at 1164–65; Merges, *Employee Inventions*, *supra* note 106, at 5.

[110] Fisk, *supra* note 101, at 1151; Merges, *One Hundred Years*, *supra* note 106, at 2217.

based on estoppel to one explicitly based on the need of the employer to bind critical knowledge to the firm.[111]

In the late-nineteenth and early-twentieth centuries, "just after the shop right evolved from an estoppel-based notion to an employment-based one," courts increasingly awarded ownership to corporate employers when R&D-oriented employees were involved in research.[112] A modern default rule emerged that generally assigned title to the firm of patents invented by all R&D employees.[113] In the absence of contract, the shop right is still the rule for non-R&D inventors whose invention is related to the employee's duties or was created with the firm's resources.[114]

In the twentieth century, courts increasingly recognized employment contracts assigning ownership of inventions to corporations, and employers increasingly made use of pre-invention assigning agreements.[115] Courts favored large-scale corporate R&D by enforcing such contracts even where technical defects created plausible doubts about enforceability. Employment contract principles were expanded to include express and implied assignment of invention rights.[116] Employee ownership under the shop right doctrine was thus cabined by the Supreme Court's decision in *Standard Parts Co. v. Peck*,[117] which held that courts should look to the intended terms of the employment contract to decide whether the firm or the employee should hold title to the invention, rather than applying a set of presumptions in favor of the employee in accordance with the "shop right" doctrine.[118]

"In 1885, only 12 percent of patents were issued to corporations . . . . [B]y 1998 only 12.5 percent of patents were issued to independent inven-

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[111] In *Dempsey v. Dobson*, the Pennsylvania Supreme Court upheld the shop right of a carpet manufacturer against the custom in the industry in the following terms:

> If a color mixer could at his pleasure carry off the recipes and color books from his employer's factory, and refuse to permit their further use except upon his own terms, it would be in his power to inflict enormous loss on the manufacturer at any moment, and not merely to disturb, but to destroy, his business. Such a custom would not be reasonable, and could not be sustained. But it is against the law. . . . ["]Even if his employé had obtained letters patent for his formula, protecting himself thereby against the public, still the employer's right to continue its use in his own business would be protected by the United States courts."

39 A. 493, 493 (Pa. 1898) (quoting Solomons v. United States, 137 U.S. 342 (1890)).

[112] Fisk, *supra* note 101, at 1164–65.

[113] Merges, *Employee Inventions*, *supra* note 106, at 5–6 (recognizing that, at least for inventions completed while employed and related to the employee's job description, firms generally receive ownership rights).

[114] Eight states, however, regulate employment contracts so that even R&D employees own unrelated inventions made off-site. *See id.* at 7–9.

[115] *See, e.g.*, Fisk, *supra* note 101, at 1191–97; Merges, *Employee Inventions*, *supra* note 106, at 7–10.

[116] Fisk, *supra* note 101, at 1179–80. At the same time, employers increasingly used pre-invention assigning agreements. *Id.*

[117] 264 U.S. 52 (1924).

[118] Fisk, *supra* note 101, at 1179–80.

tors."[119] This "corporatization of R&D" was, in part, due to a shift from inventions by individual inventors to inventions by teams of researchers in corporate R&D departments.[120] The described changes in the assignment of title (or license) to firms (primarily corporations) reflected this shift.[121] This shift also is subtly reflected in other areas of patent law.[122]

Modern trade secrets law and enforceable covenants not to compete also emerged in the late-nineteenth century.[123] Apart from trademarks, patents and copyright protections were the only intellectual property protections available to employers before the Civil War.[124] An employer's property in ideas was not recognized in American law, except insofar as it manifested itself in a physical thing, such as a machine, a blueprint, or a physical process that was patented, or in a copyrightable work.[125] Trade secrets or restrictive covenant protections for know-how or tacit knowledge were not available.[126] During this period, American courts, as a general matter, did not accept the concept that property could exist in intangible ideas or in tacit knowledge embedded in another's mind.[127] Enticement laws existed, which imposed penalties for soliciting another firm's employ-

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[119] Merges, *One Hundred Years*, *supra* note 106, at 2215 (citing U.S. Patent Office statistics).

[120] *See generally* Naomi Lamaroux & Kenneth L. Sokoloff, *Long-Term Change in The Organization of Inventive Activity*, 93 PROCEEDINGS OF THE NAT'L ACAD. OF SCIS. OF THE UNITED STATES 12,686 (1996); Fisk, *supra* note 101, at 1132, 1134 (noting "the rise of the corporate form enabled courts to see the creation and ownership of ideas as a collective enterprise").

[121] Merges, *One Hundred Years*, *supra* note 106, at 2217; *see also* Fisk, *supra* note 101, at 1141.

[122] Merges argues that by the 1920s courts were reluctant to apply the harsh traditional "naming rule," under which patents were invalidated when the wrong inventors were listed, because the new reality of corporate ownership undermined the rationale of the traditional rule and the fact of large inventive teams increased the likelihood of inadvertent naming mistakes. Merges, *One Hundred Years*, *supra* note 106, at 2218.

[123] *See generally* Fisk, *supra* note 7, at 442–43, 483–84 (describing historical development that led to the emergence of what author refers to as "corporate intellectual property").

[124] *Id*. at 466–68 ("The court's belief [in *Deming v. Chapman*, 11 How. Pr. 382 (N.Y. Sup. Ct. 1854)] that patent was the only legal protection for technology reflects a widely held view during much of the nineteenth century."). Early nineteenth century trade secrets and restrictive covenants were only enforced where incidental to the sale of a business. *Id.* at 462–68; *see also* ROBERT P. MERGES ET AL., INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE (1997) 33, 128, 346–47, 558 (providing brief reviews of the history of trade secret, patent, copyright and trademark protections, respectively).

[125] Fisk, *supra* note 7, at 463–64 ("Courts ordered the return of trade secrets if they were things but did not enjoin the use of knowledge expressed in those things. Judges emphasized the presence of physical things in part because they did not understand inchoate knowledge to be a firm's asset."); *id.* at 494 (noting that, when first recognized after the Civil War, the duty of preserving an employer's trade secrets "protected . . . mainly discrete, tangible things like recipes or drawings"); *id.* at 504 (noting that during the period from 1890 to 1930, the courts expanded the types of information that could be claimed as trade secrets, and the employers claimed as property from "the drawings of a machine to the design innovations contained in them; from the list of the customers to the knowledge of their identities, locations, needs and their goodwill; and from the precise written formula for a substance to the general knowledge of the process and techniques for making it").

[126] *Id*. at 442–43, 456–59, 463–64.

[127] *Id*. at 442–43, 456–59, 463–64, 494, 505.

ees.[128] But such laws applied regardless of whether employees had any valuable knowledge and did not prevent free employees from leaving after their contract term had expired, taking any knowledge acquired at work to a competitor.[129]

Similarly, restrictive covenants were limited to the protection of goodwill associated with the sale of a business, and were not yet recognized as enforceable post-employment restrictions.[130] Until the latter part of the nineteenth century, there was no standard legal protection that recognized the value of an employee's knowledge.[131] Even after the Civil War, courts remained hostile to the enforcement of restrictive covenants ancillary to employment contracts, reflecting, to some extent, the influence of the guild system.[132]

Starting just after the Civil War, however, courts began to protect employer's trade secrets and enforce agreements not to reveal them, especially in manufacturing contexts where the method, technique, or "know-how" had been developed by the employer. Seminal cases in intellectual property law occurred during the mid- to late-nineteenth century, recognizing complaints by factory owners seeking to prevent their machinists, designers, engineers, and chemists from taking knowledge to competitors or using it to set up their own factories in competition with their former employer.[133]

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[128] *Id.* at 450.

[129] *See* Fisk, *supra* note 7, at 450 (citing Boston Glass Manufactory v. Binney, 21 Mass. (4 Pick.) 425, 428 (1827)); *see also* Note, *Tortious Interference with Contractual Relations in the Nineteenth Century: The Transformation of Property, Contract, and Tort*, 93 HARV. L. REV. 1510, 1514–15 (1980).

[130] *See generally* Harlan M. Blake, *Employment Agreements Not to Compete*, 73 HARV. L. REV. 625, 629–32 (1960) (discussing *Mitchel v. Reynolds*, 1 P. Wms. 181, 24 Eng. Rep. 347 (Q.B. 1711), and American cases on the application of the "reasonableness test").

[131] *See* Fisk, *supra* note 7, at 465–66 (arguing that "[t]he court's belief that patent was the only legal protection for technology reflects a widely held view during much of the nineteenth century"). Fisk discusses the case of DuPont, which, as early as 1904, started to require employees to assign patents to the firm.

[132] *See, e.g.*, Keeler v. Taylor, 53 Pa. 467, 470 (1866) (refusing to restrain mechanic from setting up shop to produce platform scales after seven years of employment, despite explicit covenant in employment contract prohibiting him never to make platform scales for anyone else or to reveal knowledge received through training); Mandeville v. Harman, 7 A. 37 (N.J. Ch. 1886) (refusing to enforce restrictive covenant against trainee physician from setting up practice in Newark). *But see* Oregon Steam Nav. Co. v. Winsor, 87 U.S. (20 Wall.) 64 (1874) (upholding covenant in connection with sale of steamship not to compete in state of California).

[133] *Peabody v. Norfolk*, 98 Mass. 452 (1868), represents one of the first cases in which a court recognized an employee's confidential knowledge of his employers' proprietary process and machinery as a protectable trade secret. The court enjoined the defendant engineer (and third parties who had entered into business with him) from using a process to produce gunny cloth from jute butts that had been developed by the engineer's employer and plaintiff. Notably, the defendant engineer had agreed in writing "that he will not give any parties information, directly or indirectly, in regard to the machinery, or any portions of it" but "will consider all of said machinery as sacred to be used only for the benefit of said Peabody or his assigns, and that by all the means in his power he will prevent other persons from obtaining any information in regard to it such as would enable them to use it." *Id.* at 453.

Gradually, courts recognized a firm's right to protect the use of general knowledge of its business activities.[134] From 1890 to 1930, profound doctrinal changes expanded trade secret and restrictive covenant doctrines as a means to control the use of workplace knowledge.[135] The duty to protect trade secrets became an implied term in employment agreements, where previously it depended on an express agreement.[136] The type of knowledge to be protected by this doctrine expanded from physical things to know-how embedded in the firm (K_o) that originated in improvements made by employees. Employers obtained ownership not only of drawings or objects, but also of ideas and mental concepts expressed in them.[137] Today, the concept of a trade secret has evolved so far as to include virtually any information that derives independent economic value from not being generally known, and not being readily ascertainable by proper means by third parties that can obtain economic value from its disclosure.[138]

2. Changes in Workplace Organization.—The described developments in intellectual property law and restrictive covenants coincided with radical changes in the structure of workplace organization. They mark the shift from artisanal modes of production, to industrial and mass production in large firms, and the rise of in-house R&D departments.[139]

Before the 1850s individuals or families owned their own enterprises and managed them personally.[140] The threat of misappropriation of trade secrets was thus limited to opportunities by a few initiates and presumably controlled by personal ties and social sanctions.[141] In workshops where craft knowledge had traditionally been transmitted from master to apprentice, the apprenticeship indenture had guarded the secrets of the craft knowledge, but also the master's investment in training, during the apprenticeship's term.[142] The duty of the apprentice to guard the master's secrets during the training period was a standard term of apprenticeship agreements, corresponding to the duty of the master to instruct the apprentice.[143]

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[134] "The judges' growing understanding of the alienability and the value of employee skill led courts to recognize ever more legitimate uses for restrictive covenants. Courts eventually agreed that covenants could be used to protect 'trade secrets,' a concept that became more capacious over time." Fisk, *supra* note 7, at 458.

[135] Fisk, *supra* note 7, at 493–94.

[136] *Id.*

[137] *See id.* at 504.

[138] Judith L. Church, *Intellectual Property Aspects of Corporate Acquisitions*, *in* ALI-ABA COURSE OF STUDY MATERIALS: CORPORATE MERGERS AND ACQUISITIONS 233, 252 (2004).

[139] *See, e.g.*, Blake *supra* note 130, at 626 (noting that the treatment of restrictive covenants "at the hands of courts has reflected the evolution of industrial technology and business methods").

[140] CHANDLER, *supra* note 18, at 1; Adelstein, *supra* note 20, at 67; Fisk, *supra* note 7, at 450.

[141] *See* Fisk, *supra* note 7, at 468–69 (describing case of DuPont); Blake, *supra* note 130, at 634 (describing pre-industrial guild system).

[142] Blake, *supra* note 130, at 633.

[143] *Id.*

The duration of the apprenticeship period may be viewed as having performed a similar function to that of a restrictive covenant, in that it permitted the master to recuperate his investment in training before the apprentice could leave and begin his own workshop.[144] Further, the state's regulation of the professions prohibited apprentices from profitably using their knowledge gained at work until the apprenticeship term had expired.[145] The apprenticeship contract thus secured explicit and tacit knowledge, temporarily through the agreement (and other laws) governing the apprenticeship relation itself.

Industrialization changed the production process by introducing new technology and dramatically rearranging firm organization.[146] Industrialists scaled up and mechanized the work formerly coordinated by masters and performed in the workshop.[147] Craft knowledge previously embedded in masters now became embedded in machines and work routines.[148] Legal mechanisms were therefore required that could propertize knowledge embedded in physical assets (K_p). Intellectual property law facilitated this change. Entrepreneurs could rely on the protection afforded by patents in order to bind technology and expertise to the firm. Such propertization also allowed toolmakers and other producers of technology to sell or license their technology.[149] This encouraged investment in such products and their ready supply, facilitating the development of a market for technologies.[150]

Work on the factory floor required less skill and knowledge, substituting skill for machine-specific work routines.[151] However, certain types of knowledge could not be embedded in machines or tools.[152] The construction of machines and tools, and their maintenance required mechanics and

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[144] *Id.* at 637–42; *see also* Fisk, *supra* note 7, at 451.

[145] *See Thomas* C. Kohler, *The Notion of Solidarity and the Secret History of American Labor Law*, 53 BUFF. L. REV. 883, 895–97 (describing "comprehensive regulatory framework that gave [masters] influence over nearly every aspect of economic life by permitting the guilds substantial control over the conditions of competition") (citing K.D.M. Snell, *The Apprenticeship System in British History: The Fragmentation of a Cultural Institution*, 25 HIST. EDUC. 303, 304 (1996)).

[146] *See* Adelstein, *supra* note 20, at 67–79 (describing the shift in business organization from sole proprietorships or small partnerships to the "mechanical firm" upon the advent of new production technologies after 1870).

[147] Chandler, *supra* note 18 (providing history of emergence of large modern corporations).

[148] *See* Adelstein, *supra* note 20, at 67.

[149] *See* DAVID C. MOWERY & NATHAN ROSENBERG, PATHS OF INNOVATION: TECHNOLOGICAL CHANGE IN 20TH-CENTURY AMERICA 18 (1998).

[150] *Id.*

[151] Adelstein, *supra* note 20, at 74–79 (describing rise of "scientific management" in late nineteenth century).

[152] *See, e.g.*, Chandler & Hikino, *supra* note 52, at 31 (contrasting capital-using, scale-dependent technologies prominent in the U.S. and Britain in petroleum processing and food processing, respectively, with the "eminence of labor-intensive cotton spinning firms in Japan [that] exemplified the nation's low degree of capital accumulation and technological maturity"); *see also* CHANDLER, *supra* note 18, at 604–05.

engineers with significant expertise;[153] chemists and other experts in the sciences were needed to develop and oversee new production processes;[154] and the coordination of production required managerial and technical knowledge and experience.[155]

The development of trade secret protections and the enforcement of restrictive covenants in the late nineteenth century accompanied and reflected the new shape of corporate organization.[156] New legal protections and doctrines controlled the actions of both engineers and other experts with access to a firm's explicit knowledge and of other employees with tacit knowledge critical to a corporation's competitiveness.[157] Drafts of machine designs and other knowledge embedded in machines received protection beyond that afforded by patent and copyright law.[158] Courts read implied duties of trust and confidentiality into employment contracts, which "fit easily with the courts' new understanding that firms, not individuals, had now become pioneers of new technology and that firms hired employees precisely for their knowledge."[159] The legal system thus allowed firms to bind K_i to their structure.

The expansion of technological research and the increased use of different forms of knowledge (K_p, K_o, K_i) in the production process made their mark on the law. Legal developments have shaped the internal organization and governance of firms by assuring that they could bind employee knowledge developed during the course of work.[160] The development of trade se-

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[153] Chandler & Hikino, *supra* note 52, at 31 (describing the complementary relationship between investment in plants, equipment, and technologies by large firms and their development of the human skills and knowledge required in their operation).

[154] Alfred D. Chandler, Jr., *The United States: Engines of Economic Growth in the Capital-Intensive and Knowledge-Intensive Industries*, *in* BIG BUSINESS AND THE WEALTH OF NATIONS 63, 65–70 (Alfred D. Chandler, Jr. et al. eds., 1997) (describing "first wave" of economic growth in the United States that focused on the exploitation of capital-intensive, scale-dependent technologies in the chemical industry).

[155] *See, e.g.*, Chandler & Hikino, *supra* note 52, at 26; *see also* CHANDLER, *supra* note 18, at 604–05.

[156] *See generally* Fisk, *supra* note 7 (describing the development of trade secrets doctrine and restrictive covenants during this period); Blake, *supra* note 130.

[157] *Supra* notes 133–138 and accompanying text.

[158] *Supra* notes 131–134 and accompanying text.

[159] Fisk, *supra* note 7, at 500; *see, e.g.*, Eastman Kodak, Co. v Reichenbach, 20 N.Y.S. 110, 116 (Sup. Ct. 1892) (finding that it was Kodak's "exercise of much skill and ingenuity [that built the business,] the capital of which consists largely in certain inventions and discoveries made by its officers, servants and agents").

[160] Fisk, *supra* note 7, at 445 ("In devising new rules to govern ownership of ideas and skill, judges, treatise-writers, and lawyers perceived the issue as one of economic policy and used the law to achieve certain economic goals. In enforcing contracts—at first, only if they were express, and later by recognizing such contracts as implied—to maintain secrecy of the employer's methods, courts created a new species of "intellectual" property at the expense of older notions of artisanal independence."). As courts became aware of the value of employee knowledge to firms, they sought an expanded role for the law in facilitating economic development by allocating rights in that knowledge. Contract was rapidly becom-

crets, post-employment covenants not to compete, and non-disclosure agreements contributed to preventing the dissemination of knowledge outside the firm. All these legal developments not only affected competition, but also internal firm structure.

Without the ability to tie valuable knowledge resources to the corporation, and to continually produce and acquire new technologies, buying shares in large corporations would have been considerably less attractive to investors. Moreover, the ability to pool and combine financial resources to acquire physical assets such as machines and intangible assets such as human capital provided a fertile environment for further knowledge creation within the firm.[161] The shift in IPRs thus affected not just ownership rights to intellectual property, but, as we conjecture, ownership of the corporation itself. A further effect of creating a legal presumption in favor of corporate ownership of employee knowledge and of restricting the ability of employees to take that knowledge acquired at work to competitors, was to reduce the stake that knowledgeable workers could demand in the corporate enterprise, thus favoring the separation of ownership and control.

If the intellectual property regime had not adapted to firms' extensive appropriation of knowledge resources, different mechanisms would have emerged to avoid knowledge transfer or to encourage employees to stay longer in the firm or both. Examples of such mechanisms might have included organizational strategies that further restricted access to knowledge within the firm and special compensation packages aimed at retaining key employees.[162]

3. IPRs, Antitrust and the Rise of In-House R&D.—The expansion of intellectual property rights in favor of firms combined with the effects of tougher federal antitrust policy during the first two decades of the twentieth century contributed to the investment in the acquisition of technologies from external sources and the internalization of industrial research. The Supreme Court's decision in *Northern Securities v. United States*[163] gave expression to the U.S. Justice Department's opposition to horizontal mergers, previously encouraged by the Sherman Act.[164] Threatened with anti-

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ing the dominant legal construct for analyzing the rights and obligations of all employment relations. *Id.* at 503.

[161] Chandler & Hikino, *supra* note 52, at 26 ("An understanding of how the large industrial firm came to play the aforementioned roles requires an awareness of the complementary relationship between investment in plant and equipment (physical or tangible capital) and the human skills and knowledge developed in their operation (intangible capital). Extensive investments in large-scale plant and equipment created a fertile ground for managers and other personnel to educate themselves about both the technical skills and the organizational process of new technology."). This was also recognized by courts in the late nineteenth century.

[162] In *infra* Part V, we argue that in Silicon Valley, the absence of enforceable restrictive covenants contributed to firm's adoptions of broad-based deferred compensation packages designed to bind knowledgeable employees.

[163] 193 U.S. 197 (1904)

[164] MOWERY & ROSENBERG, *supra* note 149, at 14.

trust suits, U.S. firms, therefore, needed to seek alternative means for corporate growth. Instead of seeking dominance in a single industry, firms began to diversify, developing in-house R&D.[165]

At the same time that horizontal mergers were discouraged, federal antitrust policy did not discourage efforts to acquire new technologies from external sources prior to the 1940s.[166] Judges were tolerant of restricting patent licensing policies, thus increasing the value of patents in corporate research. More generally, the favorable treatment given to intellectual property by the judiciary, permitting their use to maintain market power without running afoul of antitrust laws, and permitting firms to appropriate the gains from investment in research, created additional incentives to pursue in-house R&D.

Legal rules thus influenced the development of particular strategies and structures in corporate organization.

B. Legal Rules and the Type of Knowledge They Bind

The different types of knowledge—K_p, K_o, and K_i—raise different challenges for legal rules that aim to bind knowledge to its proper owner.

Patent protections, encompassing the federal statutes as well as the "shop right" doctrine, employment contracts, and pre-invention assignment contracts, secure knowledge or technology embedded in physical things or products (K_p).[167] Patents confer "the right to exclude others from making, using, offering for sale, or selling"[168] an invention, which is defined as "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof."[169] In order to obtain a patent, the applicant must describe the invention and how it differs from prior art, and negotiate with the patent office specific "claims" the owner of the patent has based on the patent grant. Thus, patents secure knowledge that has been made explicit, codified (to some degree), and embedded in a physical product or process. Patents are less effective at securing tacit knowledge.[170]

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[165] *Id*. at 14–15 n.6 (citing J.L. Sturchio, Experimenting with Research: Kenneth Mees, Eastman Kodak, and the Challenges of Diversification 8, presented at "The R&D Pioneers," Hagley Museum and Library, Wilmington, Delaware (Oct. 7, 1988)) ("Eastman [Kodak], like his counterparts at other large corporations, saw in research the solution to new restraints to traditional competition created by antitrust measures. If mergers and horizontal combinations would no longer be allowed, research and development could lead to continued growth through the discovery of new markets and new businesses . . . .").

[166] MOWERY & ROSENBERG, *supra* note 149, at 15.

[167] While the federal patent statute does not directly speak to corporate ownership, the state law default rules and judicial interpretations of employment contracts and pre-invention assignment agreements facilitate firms' appropriation of gains from innovation. *See* Merges, *One Hundred Years*, *supra* note 106, at 2217.

[168] 35 U.S.C. § 154 (2000).

[169] 35 U.S.C. § 101 (2000).

[170] Winter, *supra* note 91, at 177–78 (noting that "patent protection is ineffective for processes relative to products because tacitness and non-observability are more characteristic of process than of prod-

The trade secrets doctrine secures a wide variety of firm knowledge, ranging from drawings or objects to improvements on the employer's own discoveries to inchoate know-how.[171] It protects knowledge embedded in products (K_p), knowledge of organizational routines and business practices (K_o), as well as know-how embedded in individuals (K_i). While initially covering technical information, the definition of a trade secret has expanded considerably to cover all commercially valuable information.[172] Unlike patents, the focus of trade secrets law has become the specialized knowledge of processes and techniques (K_o) that an employee learns at work, including know-how and rules of thumb. Trade secrets law thus covers tacit knowledge embedded in an employee, as well as knowledge that has been written down, articulated, or codified. This is highlighted by the fact that even negative knowledge (i.e., knowledge of what does not work to achieve a particular purpose) has been recognized as a trade secret.[173]

Covenants not to compete and confidentiality agreements secure knowledge embedded in its individual employees (K_i), including their knowledge of organizational routines and business methods (K_o). Trade secrets protection typically requires establishing what constitutes a protectable trade secret (as opposed to non-protectable knowledge), as well as a showing of "actual use or disclosure, or actual threat thereof."[174] Covenants not to compete obviate these difficulties by bluntly proscribing all competi-

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uct innovations"). *But see* ASHISH ARORA ET AL., MARKETS FOR TECHNOLOGY: THE ECONOMICS OF INNOVATION AND CORPORATE STRATEGY 116–17 (2001) (arguing that tacit knowledge can be protected by patents where "the technology to be transferred is composed of both a patented component and complementary know-how (e.g., experience using the technology)" and patent rights are strong and well-defined).

[171] Fisk, *supra* note 7 at 494.

[172] Stone, *supra* note 7, at 757. The Uniform Trade Secrets Act (adopted by at least thirty jurisdictions, *see* 6 SAMUEL WILLISTON & RICHARD A. LORD, A TREATISE ON THE LAW OF CONTRACTS § 13:14, n.69 (4th ed. 1995)) defines a trade secret as

> information, including a formula, pattern, compilation, program, device, method, technique, or process, that: (i) derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by proper means by, other persons who can obtain economic value from its disclosure or use, and (ii) is the subject of efforts that are reasonable under the circumstances to maintain its secrecy.

UNIF. TRADE SECRETS ACT § 1, 14 U.L.A. 538 (2005); *see also* RESTATEMENT OF TORTS § 757, cmt. b (1939) (defining a trade secret as "any formula, pattern, device, or compilation of information which is used in one's business, and which gives one the opportunity to obtain an advantage over competitors who do not know or use it"); UNIF. TRADE SECRETS ACT § 1(4) (1985).

[173] Fisk, *supra* note 7, at 504. Trade secrets law can, for example, be applied to protect customer lists that have been kept confidential, but not to customer information which has not been kept confidential. Metallurgical Industries Inc. v. Fourtek, Inc., 790 F.2d 1195, 1999 (5th Cir. 1986) (noting that "[o]f course, to qualify as [as trade secret], the subject matter involved must, in fact, be a secret; 'matters of general knowledge in an industry cannot be appropriated by one as his secret'").

[174] *See, e.g.*, Bayer Corp. v. Roche Molecular Sys., 72 F. Supp. 2d 1111, 1112 (N.D. Cal. 1999). The "doctrine of inevitable disclosure" has threatened to collapse this distinction. *See* Pepsico v. Redmond, 54 F.3d 1262 (7th Cir. 1995).

tion by former employees.[175] Restrictive covenants now appear in almost every employment contract.[176] Where previously non-compete clauses and other post-employment restraints were reserved for high-level management, they are now written into the contracts of at-will employees and litigated much more frequently.[177] Covenants not to compete are the most effective legal means a firm has to secure the tacit knowledge of its employees (K_i).[178]

The following chart provides a brief summary.

Table B: "Propertized" Knowledge

	Knowledge Type		
	K_p	**K_o**	**K_i**
Legal Rules and Private Contracts that Propertize Knowledge Resources	Patents Trade Secrets Employment Contracts and Pre-Invention Assigning Agreements	Trade Secrets Covenants Not to Compete Confidentiality Agreements	Covenants Not to Compete Trade Secrets Confidentiality Agreements

Source: authors' elaboration.

[175] *See, e.g.*, Water Servs., Inc. v. Tesco Chems., Inc., 410 F.2d 163, 171 (5th Cir. 1969) ("[S]ince it may be difficult to determine, as a matter of law, what is a trade secret, the covenant not to compete is a pragmatic solution to the problem of protecting confidential information.").

[176] Frank J. Cavico, *"Extraordinary or Specialized Training" As a "Legitimate Business Interest" in Restrictive Covenant Employment Law: Florida and National Perspectives*, 14 ST. THOMAS L. REV. 53, 56 (2001) ("Restrictive covenants, therefore, have emerged as a prevalent and efficacious means for an employer to protect its business interests and hard-earned competitive 'edge.'").

[177] Stone, *supra* note 7, at 739.

[178] Trade secrets and restrictive covenants are, however, complementary in that courts assessing the legitimate business interest that an employer has in enforcing the post-employment restriction will be more willing to enforce a non-competition clause where an employee has acquired confidential information that would afford a competitive advantage to another business, but less willing to do so where the employee could use or divulge only general knowledge of the business or industry. *See* Fisk, *supra* note 7, at 512–13 (discussing, inter alia, the court's reasoning in *Kodak Co. v. Powers Film Products, Inc.*, 179 N.Y.S. 325 (N.Y. App. Div. 1919)).

IV. KNOWLEDGE ALLOCATION AND TRANSACTION COSTS

A. Efficient Knowledge Allocation

The transfer and deployment of knowledge assets are subject to specific transaction costs. In this part, we discuss how firms allocate knowledge resources, as well as the special hazards affecting knowledge transactions.

1. Collocating Decision-Making Authority with Relevant Knowledge.—In order to analyze firm structure, we assume that firms will try to maximize the use of knowledge resources in the production process.[179] In order to achieve this goal, firms should collocate decision-making authority with the relevant knowledge available in the firm. A firm uses its knowledge resources most efficiently when it allocates decision-making authority to those persons or groups that have the relevant knowledge to make such decisions at the various levels of firm hierarchy.[180]

Firms must conserve knowledge resources because they are costly. All else being equal, knowledge resources are wasted where decision-making authority is withheld from those with the knowledge required to make certain decisions. Conversely, where a particular task within a firm can be accomplished more efficiently by substituting the knowledge of a supervisor or manager for that of a less knowledgeable employee, i.e. through direction of the employee, there is no need to pay the higher wage for the manager. To put it differently, if a position in the firm is occupied by someone who has more knowledge than is required to perform his work, knowledge resources are being wasted through inefficient allocation.[181]

From these observations it follows that decision-making authority should be collocated with relevant knowledge within the organization in an economizing way.[182] We call this the *Principle of Efficient Knowledge Allocation*. The principle is both positive and normative. Firm organization can be explained, at least in part, as a result of the firm's effort at maximiz-

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[179] This assumption is similar to those underlying certain economic models that firms will maximize profits and consumers will maximize their utility.

[180] *See* Michael C. Jensen & William H. Meckling, *Specific and General Knowledge, and Organizational Structure, in* CONTRACT ECONOMICS 251, 253–54 (1992) ("When knowledge is valuable in decision-making, there are benefits to collocating decision authority with the knowledge that is valuable to those decisions. There are two ways to collocate knowledge and decision rights. One is by moving the knowledge to those with the decision rights; the other is by moving the decision rights to those with the knowledge. The process for moving knowledge to those with decision rights has received much attention from researchers and designers of management information systems. But the process for moving decision rights to those with the relevant knowledge has received relatively little attention in either economics or management.").

[181] This assumes, of course, that the employee is being fully compensated for her skills.

[182] Jensen & Meckling, *supra* note 180, at 264 (arguing that "[t]he key to efficiency is to assign decision rights to each agent at each level to minimize the sum of the costs owing to poor information and the costs owing to inconsistent objectives").

ing the use of its knowledge resources. At the same time, firms must try to implement this principle in the design of their organization structure, if they are to remain efficient.

Relationships between decisional hierarchies and knowledge distribution within a firm emerge in connection with this principle. Firm hierarchy should be flatter and more decentralized, the greater the knowledge embedded in the firm's individuals.[183] In contrast, decisional hierarchies should be steeper, and decision-making authority should be more centralized, the less knowledgeable the firm's personnel and the less complex the organization's knowledge sets. In the latter case, decision rights should be assigned to a limited number of knowledgeable individuals who serve executive functions at the top of an organizational pyramid with a large base.[184]

Knowledge inputs in the form of human capital directly affect the governance structure of an organization in a way that other inputs, such as physical assets, investment capital and raw materials, do not. The value of knowledge manifests itself in solving problems and making good decisions.[185] Purchasing knowledge, but not making full use of it, or relying on those less knowledgeable to make the relevant decisions, is inefficient, and may well bring about failure in a competitive environment. It follows that purchasing knowledge is efficient only if the governance structure or allocation of decision-making authority of the organization takes that new knowledge into account, just as the purchase of a physical asset only makes sense if it is used in a productive way, or the borrowing of capital if applied to its best rate of return.[186]

However, the existence of knowledge within an organization doesn't guarantee that it will be put to its most efficient use. Knowledge resources

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[183] *See, e.g.*, Stephan R. Barley, *The New Crafts: On the "Technization" of the Workforce and the "Occupationalization" of Firms* 13–14 (CAHRS Working Paper Series, Cornell 1992) (arguing that in economies with increasingly technical workforces, "individuals rather than positions become the vessels of expertise" and organizations will adopt a more "horizontal division of labor").

[184] Demsetz suggests that those who are to produce but do not have knowledge must have their activities directed by those who possess more knowledge. Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 172.

[185] The most significant economic value of knowledge consists in its problem-solving potential. And problem-solving ultimately results in decision. Problem-solving capabilities, for the most part, are only fully engaged and sharpened when the problem-solver is confronted with real choices. Problem-solvers must therefore be genuinely engaged in a decision-making process, even if they do not have the last word. While decision-makers do not need to have a grasp of all the details of a decision, and thus can delegate some, or even much of the problem-solving, good decisions require a good grasp of the alternatives, or must rely on the opinions of those who are better informed than the decision-maker. Though formally a decision might be ratified at a higher level of hierarchy, boundedness of rationality necessarily requires the diffusion of actual decision-making within an organization.

[186] *See* Sherwin Rosen, *Contracts and the Market for Executives*, *in* CONTRACT ECONOMICS 181, 184 (Lars Werin & Hans Wijkander eds., 1992) ("Scarce talents of the most capable managers are economized by assigning them to positions at or near the top of the largest firms, where their ability is magnified to greater effect by spreading it over longer chains of command and larger scales of operations.").

are not allocated within the firm through the price mechanism. The distribution of labor within a work force is not simply a function of assigning the employee that has the most knowledge necessary to solve a particular problem. Instead, the efficient allocation of decision-making authority within organizations is subject to special difficulties that stem from the rigid nature of hierarchical organizations themselves. As Jensen and Meckling point out, inalienable decision-making rights within the firm may, over time, lead to the inefficient allocation of knowledge resources.[187]

Because there are no clear property rights in knowledge assets inside the firm, the assignment of decision-making rights to promote efficient knowledge allocation faces special difficulties. Problems of information or knowledge asymmetry make it difficult to evaluate knowledge resources. In the case of tacit knowledge, the asymmetry problem is exacerbated: individuals themselves may not be aware of what or how much they actually know. Thus, the collocation of decision-making authority with relevant knowledge is one of the most important, and perhaps most intractable, problems that a firm has to solve. The use of knowledge is not frictionless and will always generate a certain amount of waste. There are also costs due to mistaken decisions. These problems are exacerbated where decision-making authority is not collocated with the relevant knowledge.[188]

2. Centralized Versus Decentralized Decision-Making.—Scholars take different and somewhat contradictory approaches with regard to the impact that the knowledge resources have on the organization of the production process.

Some take the position that centralized organization is conducive to knowledge transfer and diffusion within firms. Kenneth Arrow, for example, argues that "authority, the centralization of decision-making, serves to economize on the transmission and handling of information."[189] Similarly, Coase's reliance on the superior allocation of resources through the fiat-control of the entrepreneur within the firm hierarchy appears to endorse this

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[187] Jensen & Meckling, *supra* note 180, at 259–60 ("[T]he internal organization of the capitalist firm is also an instance of the absence of alienable decision rights. Indeed, we distinguish activities within the firm from activities between the firm and the rest of the world by whether alienability is transferred to agents along with the decision rights. . . . While firms can sell assets, workers in firms generally do not receive the rights to alienate their positions or any other assets or decision rights under their control. They cannot pocket the proceeds. This means there is no automatic decentralized process which tends to ensure that decision rights in the firm migrate to the agents that have the specific knowledge relevant to their exercise, and that there is no automatic performance measurement and reward system that motivates agents to use their decision rights in the interest of the organization. Explicit managerial direction and the creation of mechanisms to substitute for alienability is required.").

[188] Jensen & Meckling, *supra* note 180, at 270. Thus, if decision-makers are to use the knowledge most valuable to a particular decision in making that decision, there must be a system for assigning decision rights to individuals who have the knowledge and abilities or who can acquire or produce them at low cost. In addition, self-interest on the part of individual decision-makers means that a control system is required to motivate individuals to use their specific knowledge and decision rights properly.

[189] KENNETH J. ARROW, THE LIMITS OF ORGANIZATION 69 (1974).

view.[190] Centralized authority economizes on knowledge resources by means of knowledge substitution. Knowledge substitution is of great importance especially in the case of tacit knowledge, which cannot be easily assimilated. "Direction substitutes for education (that is, for the transfer of the knowledge itself)."[191] In this way, a manager's knowledge can leverage the productivity of an employee. And more generally, it is possible "to generate more and richer coordinative activity [within firms] than can be accomplished in markets."[192] Knowledge-substitution expands the employees' productive capabilities.[193]

Other scholars, such as Hayek, point out the benefits of decentralized structures that rely on knowledge specialization.[194] Hayek argues that the market mechanism is superior and more efficient at producing goods, because knowledge is distributed throughout society and there are significant cognitive limitations faced by any set of decision-makers who would engage in the centralized coordination of productive knowledge. According to Hayek, the superiority of market production is explained by the tacit nature of much productive knowledge. Decentralized market structures are much better at allocating inherently local and context specific tacit knowledge required in the production of goods.[195] Decentralization achieved through the market is necessary, because it assures that the knowledge of particular circumstances of time and place will be promptly allocated by means of the price mechanism.[196]

We believe that firm structure will make use of both centralized and decentralized decision-making, depending on the type of knowledge used in

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[190] *See* Nicolai J. Foss, *"Coase vs Hayek": Economic Organization and the Knowledge Economy*, 9 INT'L J. OF THE ECON. OF BUS. 9, 18 (2002) ("[T]he Coase . . . notion of authority . . . assumes that a directing principal is at least as knowledgeable about the relevant tasks as the agent being directed.").

[191] Demsetz, *The Theory of the Firm Revisited*, *in* THE NATURE OF THE FIRM, *supra* note 5, at 172.

[192] R. P. Rumelt, *Inertia and Transformation*, *in* RESOURCE-BASED AND EVOLUTIONARY THEORIES OF THE FIRM 124 (C.A. Montgomery ed., 1995).

[193] According to Conner & Prahalad: "[K]nowledge-substitution is a fundamental response to cognitive limitations, having the effect of economizing on them . . . . A primary effect of firm organization—of the authority relationship—is to cause an individual to use the knowledge of another *before* the former fully understands or agrees with it." Conner & Prahalad, *supra* note 4, at 485.

[194] *See generally* sources cited *supra* notes 33–35 (discussing benefits of decentralization).

[195] F.A. Hayek, *The Use of Knowledge in Society*, 35 AM. ECON. REV. 519, 521–22 (1945) ("It is with respect to this that practically every individual has some advantage over all others in that he possesses unique information of which beneficial use might be, but of which can be made only if the decisions depending on it are left to him or are made with his active cooperation. We need to remember only how much we have to learn in any occupation after we have completed our theoretical training, how big a part of our working life we spend learning particular jobs, and how valuable an asset in all walks of life is knowledge of people, of local conditions and special circumstances.").

[196] *Id.* at 528 ("Through [the price system] not only a division of labor but also a coordinated utilization of resources based on an equally divided knowledge has become possible."). However, Hayek does not explain why there is organization of production inside firms at all, and what implications firm organization would have for knowledge development. Hayek treats large firms, which do not use the price mechanism to allocate knowledge resources in their internal structures, as individuals.

the production process and on other factors, such as the nature of the problem or problems that the organization must solve. The relations between producers within the firm clearly include a division of knowledge among different persons involved in production.[197] Firms *centralize* certain decisions and *decentralize* others. Indeed, decentralization achieved through specialization is at least as important as the centralization of decision-making in steeper hierarchies. The efficient use of knowledge resources requires decentralized decision-making under some circumstances—in markets or firms—and centralized decision-making under others.

The *degree* to which knowledge substitution takes place affects firm organization. The potential for knowledge substitution is a necessary condition for greater centralization and steeper hierarchies. But it is not a sufficient condition. Where knowledge substitution is counterproductive or impossible, employees must rely on their own knowledge and firm organization will tend to be characterized by greater decentralization and flatter hierarchies.[198]

Nickerson and Zenger argue that markets are best at handling one type of problem (low-interaction/decomposable problems), whereas hierarchies are best at handling another type (high-interaction/non-decomposable problems).[199]

A problem is a low-interaction/decomposable problem if its solution does not depend on interactions among different knowledge sets. In searching for solutions to such problems, individuals thus can apply their knowledge independently from one another.[200] And the subsequent aggregation of one independent effort with the independent efforts of others who possess different knowledge sets can uncover a valuable solution to the problem. One example of such a problem is the design of a higher-performing personal computer. Performance can be increased by independently improving any number of subsystems, such as the disk drive, the monitor, or the CPU. Such problems "can be subdivided into subproblems, each of which draws from rather specialized knowledge sets."[201]

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[197] Hayek was the first to point out the importance of the division of knowledge:

> Clearly there is here a problem of the *Division of Knowledge* which is quite analogous to, and at least as important as, the problem of the division of labour. But while the latter has been one of the main subjects of investigation ever since the beginning of our science, the former has been as completely neglected, although it seems to me to be the really central problem of economics as a social science.

F.A. von Hayek, *Economics and Knowledge*, ECONOMICA, Feb. 1937, at 49.

[198] *See* Stiglitz, *supra* note 52, at 19 ("In the firm, moving from simple repetitive work under central control (Taylorism) *to more complex knowledge-based* work requires a move towards a more decentralized and participative workplace." (emphasis added)).

[199] Jack A. Nickerson & Todd R. Zenger, *A Knowledge-Based Theory of the Firm—The Problem-Solving Approach*, 15 ORG. SCI. 617, 628 (2004).

[200] *Id*. at 619.

[201] *Id*. at 620.

A problem is a high-interaction/non-decomposable problem if its solution is highly dependent on interactions among different knowledge sets. Such problems cannot be separated into subproblems and therefore cannot be addressed by individuals familiar with only one particular knowledge set. The design of a leading edge microprocessor circuit is currently such a problem that "demands numerous knowledge sets that extensively interact in determining the value of solutions . . . . [T]he value of any particular design change will interact with a host of other potential design changes determined by actors possessing distinctly different knowledge sets."[202] In order to solve such problems, "heuristic search" methods must be used.[203] Heuristic search requires the development of an understanding of complex patterns of knowledge interactions and the selection of trials that maximize the probability of finding a high-value solution. Extensive communication and knowledge transfer among individuals with different knowledge sets are required to solve such problems.

These different types of problems are handled most efficiently by different governance structures. Markets are ideally suited for the solution of decomposable problems by encouraging specialists to pursue trials that exploit their particular expertise. For instance, the personal computer is produced from components created worldwide, and IBM accordingly outsourced the production of the components of its PCs.[204]

The cost of using markets increases, however, with increasingly non-decomposable problems.[205] In this case, solutions must mitigate knowledge-based exchange hazards that arise from the public goods nature of knowledge. The best such solution is firm hierarchy in two forms[206]: authority-based hierarchy and consensus-based hierarchy. Authority-based hierarchy is consistent with centralized management of knowledge by individuals who supposedly are more knowledgeable, and is most effective at solving problems of relative complexity, while economizing knowledge transfer. In contrast, the solution of high complexity problems requires greater decentralization and thus consensus-based hierarchy, as no particular actor will be knowledgeable enough to direct a heuristic search.[207]

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[202] *Id*.

[203] *Id*. at 621.

[204] CHANDLER, *supra* note 6, at 137–38 ("Estridge completed contracts with suppliers of components. Tandon made the disk drives in California; Zenith the PC power supplies in Michigan; the Silicon Valley division of SCI systems (a contract manufacturer) the circuit boards; a Japanese firm, Seiko Epson, the printers; IBM's plan at Charlotte, North Carolina, the board assemblies; and its plant at Lexington, Kentucky, the keyboards.").

[205] Nickerson & Zenger, *supra* note 199, at 623–24. The authors argue that markets exacerbate knowledge exchange hazards, discouraging investments in co-specialized knowledge and development of a common language that are essential to a heuristic search.

[206] *Id*. at 624–27.

[207] *Id*. at 623–24.

B. Knowledge Hazards

In addition to the difficulties of efficient knowledge allocation already described, there are additional hazards that may impede efficient knowledge use by the firm, even with proper care to collocate decision rights with relevant knowledge. Although traditional moral hazards, such as shirking, will occur when an employee fails to apply her knowledge with the expected effort, there are additional hazards that are specific to knowledge resources. These specific knowledge hazards are caused by the public goods characteristics of knowledge resources and also by the tacit nature of knowledge.

1. Leakage.—Knowledge resources, as already indicated, have public goods characteristics. A public good has two critical features: non-rivalrous consumption and non-excludability. Non-rivalrous consumption means that the consumption of the good by one individual does not detract from the ability of others to enjoy its consumption. Non-excludability means that it is difficult, if not impossible, to exclude an individual from enjoying the good.[208]

Thus, knowledge resources are subject to significant hazards in market transactions. If one wants to sell knowledge in the market, she will have to disclose something about what she intends to sell so that the buyer develops an interest in buying. Just by doing so, the seller has already lost some of her property.[209] Worse yet, the revealed knowledge may be used by people who receive the information other than the transferee, including potential competitors, thus undermining the ability of its proprietor to extract rents from her ownership.

Knowledge transfers are thus vulnerable to "leakage." Leakage refers to the unwanted transfer of knowledge by its proprietor, permitting a third party to benefit from the knowledge without compensating the knowledge proprietor.

As we already discussed in Part III, while intellectual property protections are directed precisely to solving the problems of knowledge transfer, they rarely confer perfect appropriability,[210] and do not apply to all kinds of knowledge. Markets for knowledge and information therefore depend critically on reputation, on repeated interactions, and on trust.[211]

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[208] *See, e.g.*, Joseph E. Stiglitz, Knowledge As a Public Good, http://www.worldbank.org/knowledge/chiefecon/articles/undpk2/index.htm (last visited May 15, 2007) ("Knowledge of a mathematical theorem clearly satisfies both attributes [non-rivalrous consumption and non-excludability]: if I teach you the theorem, I continue to enjoy the knowledge of the theorem at the same time you do. By the same token, once I publish the theorem, anyone can enjoy the theorem. No one can be excluded. They can use the theorem as the basis of their own further research. The 'ideas' contained in the theorem may even stimulate others to have an idea with large commercial value . . . .").

[209] Stiglitz, *supra* note 52, at 13.

[210] *See supra* notes 94–96 and accompanying text.

[211] Ashish Arora & Robert P. Merges, *Specialized Supply Firms, Property Rights and Firm Boundaries*, 13 INDUS. & CORP. CHANGE 451, 470 (2004).

It is easy to see the benefits of integrating knowledge production rather than procuring such resources through market transactions when the knowledge used in the production process is most susceptible to hazards—as, for instance, in the case of K_i. We develop this latter point in Parts V.A and V.F, below. To avoid leakage, firms also must design other mechanisms, such as compensation strategies, in accordance with the knowledge type they deploy. We will discuss particular compensation systems used by high-tech firms and law firms in Parts V.D and V.E. Because such mechanisms can ameliorate the hazards to which knowledge resources are susceptible—even if imperfectly—knowledge is usually distinguished as an *impure public good*.[212]

2. Hoarding or Failure to Share.—Knowledge transfers within organizations are subject to special problems as well, given that knowledge that is not actively communicated may not be observed at all. The first problem arises from the fact that the exclusive possession of knowledge may serve the career goals of individual employees. For example, actors may fail to share knowledge in order to secure their decision-making authority or to extract other advantages. Hoarding or failure to share knowledge is potentially attractive to an employee (especially for managers), because the employee may monopolize such knowledge and thereby extract rents. Such opportunistic behavior could potentially provide very significant gains for the individual and lead to significant inefficiencies for the organization.

The second problem refers to the underutilization of knowledge in the absence of opportunism. In this situation, the knowledge transferor is committed to sharing his knowledge. This may result from insufficient communication skills, insufficient knowledge on the part of the transferee, insufficient organizational opportunities for knowledge exchange, or the lack of appropriate settings within which to communicate tacit knowledge.

Whatever the motivation, hoarding or failure to share are hard to detect or measure. As a result, knowledge resources existing within the firm may be underutilized.[213] Thus, even if decision rights are collocated with the most appropriate knowledge, transaction costs from knowledge transfer are therefore subject to special hazards that may interfere with the efficient allocation of knowledge resources.[214]

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[212] Stiglitz, *supra* note 208 ("[B]ecause the returns to some knowledge can, to some extent, be appropriated (there is some degree of non-excludability) knowledge is often thought of as an *impure* public good.").

[213] Note that we are not referring here to the problem of bounded rationality, which generates constant underutilization of knowledge. Rather, we address situations in which knowledge could otherwise be effectively used if disclosed by its donor.

[214] *See, e.g.*, Jensen & Meckling, *supra* note 180, at 267 ("Because all individuals in a firm are self-interested, simply delegating decision rights to them and dictating the objective function each is to

V. REVISITING SOME ASPECTS OF FIRM ORGANIZATION FROM THE KNOWLEDGE RESOURCES PERSPECTIVE

A. Correlating Knowledge Structures and Governance (Decisional/Ownership) Structures

In this part, we apply the principles and the typology we have developed to explain variations in the organization (and the boundaries) of firms that engage in different types of firm production.

We argue that production will be organized within a firm (as opposed to the market), as long as the firm can sell knowledge or expertise or can add knowledge or expertise to a product or service that is already being sold in the market. Holding all the other variables constant, we argue that a firm's type and degree of knowledge specialization constrains its organizational choices. We advance several hypotheses, for which we then produce evidence in subsequent sections.

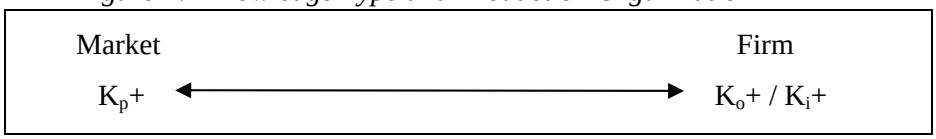
To that end, we advance the following hypotheses:

Hypothesis 1: The more the production relies on K_p, the more we will expect production to be organized by means of the market mechanism.

Hypothesis 2: The more the production relies on K_o and K_i, the more we will expect production to occur within the firm.

Thus if we imagine a continuum of knowledge inputs from purely K_p inputs at one extreme to purely K_i inputs at the other extreme, we would expect to find production taking place exclusively through market transactions in the first instance, but exclusively within firms in the second instance.

Figure 1: Knowledge Type and Production Organization



Assume now that some level of tacit knowledge or K_i is applied in the production process. Production will thus take place in the firm. The structure of the firm governing the production process will then be more or less centralized depending on the level of K_p added. Because tacit knowledge is embedded in an individual, and because the more the knowledge is embed-

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maximize is not sufficient to accomplish the objective. A control system that ties the individual's interest more closely to that of the organization is required.").

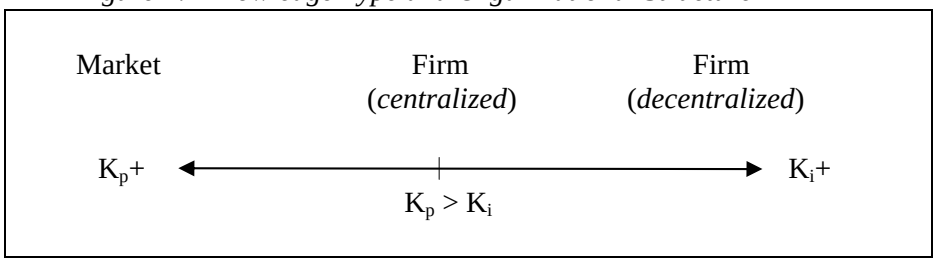
ded in an individual, the less effective the management of knowledge through centralized governance structures, it follows that:

Hypothesis 3: The greater the reliance on K_i, the more decentralized the firm decisional hierarchies that will govern the production process.

Hypothesis 4: The greater the level of K_p, and the less reliance is placed on K_i, the greater the centralization of decisional hierarchies that govern firm production.

Hence on the continuum that describes the organizational structure of the firm if at one extreme a firm predominantly relies on K_p, this firm will have a centralized governance structure. At the other extreme, if a firm uses exclusively K_i, it will have a very decentralized governance structure.

Figure 2: Knowledge Type and Organizational Structure



The table below distinguishes some basic types of industries according to the nature of the knowledge that they use. The knowledge type that is used (K_p, K_o, K_i) varies depending on the different production technologies and techniques in a particular industry, and the organizational structure reflects the relative deployment of different knowledge types.[215] Of course there is a mixture of K_p, K_o and K_i in all types of firms. What changes is the degree to which each of these variables enters into the production process of each firm type as suggested above.

[215] In future elaborations, we intend to rely on SIC codes to identify existing bodies of empirical data in the relevant specialized literatures.

Table C: The Structure of Knowledge and the Structure of the Firm

Firm Structure	Example	Knowledge Structure
1. Sole Proprietorship—Simple Manufacture	Workshop	K_i K_p- K_o-
2. Taylorist Mass Production—C-Form	Ford	K_p+ K_o K_i-
3. Mass Production—Chandler's M-Form	DuPont	K_p+ K_o+ K_i
4. High-Tech Engineering	Cisco; Silicon Valley Startups; Biotech Startups	K_i+ K_o+ K_p-
5. High level Professional Services[216]	Law Firms	K_i+ K_o K_p-

In the following, we discuss some of the characteristics of these different firm types and how the different types of knowledge resources they deploy have affected their internal governance structures.[217]

B. The Sole Proprietorship or Small Partnership

The sole proprietorship or small partnership was the typical American enterprise before the Civil War. These business organizations had easily identifiable individuals fully responsible for the obligations of the business.[218] For example, the system common in small factories prior to 1870

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[216] Although of considerable interest to us, we must leave the discussion of franchises in the low-level service industry, such as the McDonalds franchise, to a future article. Such a firm can be characterized as having the following knowledge structure: K_p, K_o+, K_i-.

[217] Demsetz has advanced some of the relations between knowledge resources and firm governance structure:

> Some firms, for example, earn revenues by performing repetitive and routine activities most of the time. Others are preoccupied with highly innovative activity. The difference in the tasks faced by these firms, I believe, dictates differences in their organization structures and compensation systems. Less hierarchy can be tolerated by firms engaged in innovative activity, and decision rights are probably dense in the middle of the hierarchy that exists. This is because the problems faced by such a firm, relative to one engaged in repetitive activities, cannot be solved as easily as routinizing procedures with rules and regulations. It should also be the case that a difference in compensation methods is required because decisions must be more decentralized for firms that engage in, for example, genetic research. Greater reliance on profit-based compensation is required to bring objective functions of dispersed holders of decisions rights into closer accord.

Demsetz, *supra* note 57, at 279–80.

[218] Adelstein, *supra* note 20, at 67.

had particular features: large investments were rare; no formal employment contracts existed; production rarely required complicated or costly machinery; workers mainly did so at home and owned their tools, leading to a considerable degree of personal autonomy; the timing and pace of work, within limits, were left to workers; there was no need to tie up capital in expensive equipment.[219]

Personal autonomy and decentralization in the production process emerged from the type of knowledge required in the production process. Workers were artisans who had command of their work. They had the tools and, most importantly, the knowledge necessary to perform the work. As the knowledge required to perform the handiwork was, relatively speaking, not very complex or technologically sophisticated, most of the manufacturing process depended on the expertise and work experience embedded in each worker (K_i). Thus, the structure of the production process was significantly decentralized and workers were assigned autonomy to control their tasks. This governance structure permitted an efficient knowledge allocation as the artisans had sufficient knowledge to perform their tasks independently.

Systems of apprenticeship also existed during this period, where an artisan controlled and managed the production process and exercised decision-making authority. This governance structure also can be explained in terms of the nature of the knowledge resources necessary for the production: the master who had greater technical knowledge (K_i+) retained the decision rights as his apprentices developed their skills (K_i–). The knowledge differential determined the hierarchy between masters and apprentices in the firm.

C. Mass Production Firms

The governance structures typical of small manufacturing partnerships began to change with the advent of new technologies after 1870.[220] These technologies yielded significant inventions and new products. Small factories gradually became manufacturing companies, and their focus changed to large-scale production.[221] Soon large amounts of immobilized capital in the form of special machinery located on the production floor (K_p) became a

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[219] *Id.* at 67, 74–75.

[220] *Id. See generally*, ALFRED D. CHANDLER, JR., THE VISIBLE HAND: THE MANAGERIAL REVOLUTION IN AMERICAN BUSINESS 272–81 (1977). According to Chandler, these developments were characterized by an increase in the number of engineers, a new emphasis on formal science, and efforts to rationalize the operations of the machine shop. Engineers played a significant role in the development of American manufacturing. There was a rationalization of the accounting processes, coordination and scheduling, operational scale, monitoring and coordination by managers, creation of formal procedures structuring new hierarchies. It is important to note that this is also the beginning of rationalization of organizational routines (K_o). Companies developed professional management tools and improved their routines through conscious study and knowledge of the organization process.

[221] *See* CHANDLER, *supra* note 220, at 277.

key asset in the mass production system. This increasing reliance on K_p in the productive process determined many of the organizational features of mass production corporations.

Once knowledge became embedded in machines and work routines, workers increasingly became more replaceable. Taylor's system of scientific management perfected the mechanization of the production floor, taking the economies of mass production further than companies had before. The goal of Taylor's scientific management was to embed all of the decentralized knowledge previously dispersed among employees into machines and production routines under the more expansive control of management.[222]

This "physical separation of thinkers and doers" required a separate class of managers.[223] Well-educated employees, who planned, executed and controlled production and marketing with the help of scientific knowledge, sat at the top of the hierarchy—the managerial class. These highly skilled employees were responsible for the organization of the firm and most of the legal decision-making rights. At this level of the hierarchy, the new corporations of the twentieth century dramatically increased the level of technical learning and tacit knowledge (K_i). In contrast, the heavy use of machines (K_p) and organizational routines (K_o) permitted the use of unskilled workers, who became readily replaceable without causing any measurable loss to the company.[224]

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[222] According to Adelstein,

> Taylor's alternative solution to the planner's problem in the shop was to break the workers' monopoly with the hammer of science and replace the decentralization of power based on craft knowledge with a hierarchically organized workplace in which expert managers told workers precisely what to do and how to do it. Every task in the shop would be reduced to a series of minute 'elementary operations' performed by a man on a machine, and with the aid of a stopwatch and a strong, agile worker, the time needed to complete each such operation would be computed. . . . [M]anagement could . . . thus gain possession of all the knowledge needed to control the shop. It could then systematize and codify it, and return it to workers in the form of detailed instructions.

Adelstein, *supra* note 20, at 76.

[223] *Id*. at 77.

[224] We do not maintain that line workers were necessarily less knowledgeable, but that the system was designed so as to reduce reliance on knowledge embedded in the employee for purposes of operating the assembly line. *See* William Lazonick & Mary O'Sullivan, *Big Business and Skill Formation in the Wealthiest Nations: The Organizational Revolution in the Twentieth Century*, *in* BIG BUSINESS AND THE WEALTH OF THE NATIONS 501, 519 (Alfred D. Chandler, Jr. et al. eds., 1977) ("In contrast to Britain, however, American reliance on skilled shop-floor labor to coordinate production activities was generally short-lived, as U.S. industrialists developed technological and organizational alternatives to leaving skills, and the control of work, on the shop floor. By employing unskilled immigrants from Eastern and Southern Europe, by investing in deskilling technological change, and by elaborating their managerial structure to plan and coordinate the productive transformation, U.S. industrial capitalists attacked the craft control that workers—typically of British and German origin—had staked out during the 1870s and 1880s."). The authors describe that in the first decades of the nineteenth century, top management positions were occupied increasingly by university graduates in search of careers that would demand the application of science to industry.

These developments are consistent with our theory. Our theory predicts that governance structures become more centralized when K_p predominates in the production process. This is necessary to achieve an efficient allocation of knowledge resources: decision rights must flow to employees with costly K_i at the upper-levels of the firm hierarchy. Conversely, decision-making will become more decentralized the greater the reliance is on K_i at other levels of a firm's hierarchy, because efficient knowledge allocation demands the collocation of decision rights with costly knowledge resources.

1. The Shift from C-Form to the M-Form Structure.—Chandler distinguishes three main stages in the evolution of American manufacturing firms. The period between 1880 and the first World War, after the first wave of new technologies, was characterized by capital accumulation, large investments in physical assets, and the expansion of production to achieve gains of scale.[225] During this period, a heavy reliance on K_p—in the form of technology applied to the development of machinery—coincided with the rationalization of production processes that ultimately led to centralized decision-making in the so-called C-form corporation. The second period, from 1914 to 1950, was dominated by the new internal combustion engine and its applications in the motor vehicles industry. In this period too, firms made large investments in tangible capital. The third period, from the end of World War II to the 1980s, was characterized by a shift from the accumulation of tangible capital to intangible capital.[226] Growth came from knowledge and science development rather than mere expansion of scale.

Chandler's thesis is that structure follows strategy.[227] He argues that the pursuit of (the strategy of) product diversification[228] led American firms to adopt the so-called multi-divisional firm structure, or M-form, which is characterized by greater decentralization of decision-making processes.[229]

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[225] Chandler, *supra* note 154, at 63–64.

[226] *Id.* at 64. Empirical evidence shows that since the 1960s, the number of R&D scientists and engineers substantially increased from 348.4 thousand in 1965 to 726 thousand in 1989. *Id.* at 38–39.

[227] ALFRED D. CHANDLER, JR., STRATEGY AND STRUCTURE: CHAPTERS IN THE HISTORY OF THE AMERICAN INDUSTRIAL ENTERPRISE 14 (1990).

[228] *Id.* at 42–43, 45 ("In those industries most affected by the new markets and new technology, growth came more by going overseas and still more by diversification. Of these two strategies, diversification was far more responsible for the adoption of the 'decentralized' structure than overseas expansion. Diversification came when leading companies in these technologically advanced industries realized that their facilities and the scientific know-how of their personnel could be easily transferred into the production and sale of new goods for new markets.").

[229] According to Chandler's definition, "An enterprise can be said to have adopted the new [M-] form if it came to have a general office with executives whose primary tasks were general rather than functional and if it also had at least two major multidepartmental, relatively autonomous divisions." CHANDLER, *supra* note 227, at 325. This pattern of organization was gradually adopted by more industries as they started to expand their activities through diversification after the Second World War. *Id.* at 42. Chandler mentions the examples of Hercules Powder and Monsanto (before 1940) and Celanese Corporation of America, Columbia Carbon, Carborundum, American Cyanamid, Koppers, Pittsburgh

Chandler's history of American manufacturing firms provides support for our theory: When American firms relied mostly on K_p, they dramatically centralized their governance structures. But when firms deployed increasing levels of K_i and K_o in R&D for product improvement, innovation, and diversification, they were forced to decentralize to some degree. Knowledge inputs can thus help explain the changes in firm structure that Chandler identifies.

Chandler shows that after the 1890's, the great manufacturing companies centralized their headquarters. The headquarters were responsible for decisions concerning nearly all the activities of the enterprise's plants or marketing units.[230] Embedding knowledge inputs in products and machines and standardizing production processes enabled economies of scale.[231] According to industry insiders, the most important benefits of the new unified form of organization included the utilization of machinery and equipment to its fullest capacity, the ability to replace striking workers by switching operations to other plants, and the benefits from skilled managers at the top of the hierarchy making decisions and supervising the enterprise in its entirety.[232] Hence the major significance of K_p for such firm organization and the diminished use of K_i, concentrated at the upper levels of the organizational hierarchy.

After the first stage of centralization, firms began to make use of their existing knowledge and skill-sets to diversify into related products and industries. This diversification, however, typically brought about a measure of decentralization, given the different expertise required to run different types of businesses.

Coke & Chemical, Glidden, Atlas Powder, Shell Oil and Phillips Petroleum. *Id.* at 44–45; *see also id.* at 48 (discussing the effect of product diversification in oil enterprises). Shell, Standard of California, Phillips Petroleum, Texaco, Standard (Indiana), Standard of Ohio, and continental Oil set up autonomous divisions to administer their new chemical products. *Id*. at 47–48.

[230] *Id.* at 31.

[231] *Id*. ("The transformation of a loose alliance of manufacturing or marketing firms into a single consolidated organization with a central headquarters made possible economies of scale through standardization of processes and standardization in the procurement of the materials. Of more significance, consolidation permitted a concentration of production in a few large favorably located factories. By handling a high volume of output, consolidated factories reduced the cost of making each individual unit . . . .").

[232] See a comment from Charles R. Flint, organizer of the United States Rubber Co. in 1899, regarding the benefits of consolidated management:

> The following are the principal ones: raw material, bought in large quantities is secured at a lower price; the specialization of manufacture on a large scale, in separate plants, permits the fullest utilization of special machinery and processes, thus decreasing costs; the standard of quality is raised and fixed; the number of styles reduced, and the best standards are adopted; those plants which are best equipped and most advantageously situated are run continuously in preference to those less favored, in case of local strikes or fires, the work goes on elsewhere, thus preventing serious loss . . . ; greater skill in management accrues to the benefit of the whole, instead of the part; and large advantages are realized from comparative accounting and comparative administration . . . .

Id. at 33, 34.

In the beginning of the twentieth century, the leading enterprises faced increasingly complex administrative problems due to technological advances and the systematic application of science to industrial production.[233] These developments exposed a serious weakness in centralized firm structures: there were too few decision-makers for the great number of complex decisions that needed to be made.[234] A single management team could no longer master the disparate bodies of knowledge needed to run different lines of business, especially in science-intensive industries. Different types of K_p deployed in the different production processes added significant complexity. Supply lines and margins responded to different market conditions in different businesses. Different organizational routines were required—getting quotes for the price of raw materials, for example, differed significantly from one business to the next, as did the establishment of supply lines and related logistics. Supply lines for different products were subject to different hazards, market fluctuations, environmental events, etc., requiring new and specialized organizational routines. Increasing complexity required different types of management experience—with different types of K_i.[235]

Organizations evolved by spreading decision-making responsibilities among those managers with greater specialized knowledge of different product lines and within each division among department heads with functional responsibilities. This decentralization process allocated knowledge resources more efficiently. The more bodies of knowledge (different types of K_p) a firm needed to master, the more decentralized their organizational structure needed to become—to enhance the use of individual knowledge (K_i) available within the firm.

a. The Dupont Case.—The case of DuPont during the first two decades of the twentieth century illustrates our theory that knowledge concerns have driven the organizational evolution of mass production firms. DuPont built large research departments to generate new products and improve existing ones.[236] The application of science through institutionalized research resulted in diversification as new products were developed.[237] Di-

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[233] *Id*. at 42.

[234] *Id.* at 41.

[235] Chandler and Hikino argue that as capital-intensive and science-based industries grew, entering into new product markets, the initial centralized structure (unitary or U-form) became inefficient. "Senior managers became acutely aware that they did not have the time or the competence to coordinate and monitor—or to devise and implement—long-term strategies for their units operating in different geographical and product markets." Chandler & Hikino, *supra* note 52, at 35. They started to adopt a decentralized structure to meet their organization necessities (the multidivisional M-form).

[236] *See* CHANDLER, *supra* note 220, at 84–88.

[237] *Id.* at 43.

versification, in turn, resulted in increased complexity of operational and entrepreneurial capabilities.[238] Dupont's centralized control placed ultimate decision-making authority in the hands of executives who did not always possess the relevant knowledge to manage their lines of business. Recognizing this, DuPont's Chairman, Harry Haskel, exempted DuPont's dye business from centralized control, even as DuPont was concentrating all decision-making authority concerning manufacturing operations in a single executive Vice Presidency around 1919.[239] Haskell believed that "[i]t may be that it would be better for a few years to carry on the dye business as a separate entity . . . because it is a developing, unstandardized industry and should merit independent attention."[240]

Haskel, who at the time was one of the leaders of American industry, thus recognized both that standardized production techniques facilitated centralized control, but that decentralization of decision-making authority was necessary where complex non-decomposable problems needed to be addressed by specialized managers with tacit knowledge in a specialized field.

When the government imposed antitrust restrictions on DuPont's military powder business, DuPont saw itself with idle capacity in one of its plants and intensified its strategy to diversify its product lines. DuPont's search for potential products was clearly guided by a concern for making use of its existing knowledge sets. According to Chandler, the products that DuPont chose were in "a field where the company's technological experience, training, and resources could pay off."[241]

Seeking diversification based on its nitrocellulose experience with gunpowder, DuPont bought the International Smokeless Powder & Chemical Company, a manufacturer of both explosives and pyroxylin lacquers. Subsequently, DuPont set up a small pilot plant to produce pyroxylin-based artificial leather. The operation proved successful, and DuPont's Executive Committee decided to purchase one of the leading firms in the field, Fabrikoid Co., to "learn more about the business" instead of building its own artificial leather plants.[242]

DuPont also pursued the production of pyroxylin from nitrocellulose based on short-staple cotton. However, upon investigation, it was concluded that DuPont would have difficulty supplying companies with their nitrocellulose requirements. Firms would not buy from outsiders, because they would not sacrifice control and supervision of their products. To act as a supplier, DuPont would have to become knowledgeable about the details of manufacturing or composition of their customers' products. But firms

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[238] *Id.* at 44.
[239] *Id*. at 68.
[240] *Id.*
[241] *Id.* at 81.
[242] *Id.*

regarded these details as valuable trade secrets, which they would not share with a potential competitor.[243] Because of the close coordination required in the industry between supplier and manufacturer, DuPont instead pursued a policy of vertical integration.[244]

DuPont's increasing product diversification resulted in inefficiencies in knowledge allocations. According to Chandler, "[t]he development of plans and the appraisal of activities were made harder because executives with experience primarily in explosives were making decisions about paint, varnishes, dyes, chemicals and plastic products. Coordination became more complicated because different products called for different types of standards, procedures and policies."[245] As a consequence, the company's new ventures suffered from extremely poor performance.[246]

Initially, DuPont stuck with its old centralized organization that concentrated decision rights in the hands of executives specialized in explosives. Proceeding under this familiar organizational structure, DuPont lost money on every product except explosives, accumulating high deficits in the area of paints, varnishes, and cellulose products.[247] The company then studied the problem and, after a six-month investigation, concluded that a new management structure was necessary.[248] In a report that envisaged the restructuring of DuPont, it was concluded that "no member of the Executive Committee should have the direct individual authority or responsibility which he would if he was in charge of one or more functional activities of the Company. His relations to such functions should be advisory only."[249] Further, according to the new plan, "the head of each Industrial Department [would henceforth] have full authority and responsibility for the operation of his industry, subject only to the authority of the Executive Committee as a whole."[250]

In the face of product diversification, DuPont thus decentralized its decisional hierarchy. The new General Managers would handle the day-to-day administration of the divisions, whereas the Executive Committee would henceforth be responsible for over-all coordination, appraisal, and policy planning.[251] In 1921, DuPont established autonomous, multi-departmental divisions and a general office with staff specialists and general

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[243] *Id.* at 82.

[244] *Id.*

[245] *Id.* at 91.

[246] *Id.* at 92.

[247] *Id.* at 104 ("The strategy of diversification seemed to promise little more than difficulties and deficits.").

[248] *Id.* at 94.

[249] *Id.* at 107 (quoting Report to Executive Committee from Subcommittee on "Du Pont Company Organization" (Aug. 31, 1921)).

[250] *Id.*

[251] *Id.* at 107.

executives. Each division had several departments and its own central office to administer them.[252]

The new multi-divisional structure—called the M-form—promoted an efficient allocation of knowledge resources.[253] Chandler cites as one reason for the success of the decentralized structure the fact that it "removed the executives responsible for the destiny of the entire enterprise from the more routine operational activities," providing them with more "time, information and . . . psychological commitment for long-term planning."[254] Decentralization also benefited the organization by delegating important business decisions to those individuals with relevant business knowledge (K_i). Senior executives of the Company increasingly specialized, began to carry out entrepreneurial activities, and focused on strategic decisions. Decentralization further resulted in the collocation of decision rights with relevant knowledge in that general managers of the divisions were granted authority to manage operations in their own areas of expertise. Once the new structure was in place, "losses were soon converted into profits."[255]

DuPont's development shows that the decentralization of decisional hierarchies became necessary where the development and production of new products required mastery of new knowledge sets that had not yet been standardized, as well as research and individual expertise to find solutions to new and complex problems. According to Chandler, "[d]iversification . . . brought the new decentralized structure, not because it increased the total output or size of operations, but because it so quickly enlarged the number and complexity of both tactical and strategic administrative decisions."[256] As discussed above, the nature and complexity of the problems to be solved affects the degree of decentralization required by the decisional hierarchy. More complex and non-decomposable problems require more decentralization. In the case of DuPont's new product lines, the problems encountered were both complex and industry specific, and thus could not be analyzed and processed in the same fashion by a single management team. They required "the creation of a multidepartmental autonomous division for the administration of each major line of products."[257]

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[252] *Id.* at 111.

[253] Chandler argues,

> If the general officers were better equipped to handle over-all strategic decisions, the division managers had full authority and the necessary facilities to make the day-to-day tactical ones. As each controlled the functional activities needed for making and selling one major line of products, each could determine, within the framework set and funds allotted by the Executive Committee, the most efficient ways to use the resources at his command.

Id. at 111.

[254] *Id.* at 309.

[255] *Id.* at 112.

[256] *Id.* at 362.

[257] *Id*.

b. Centralized structures.—In the electrical (including electronics), power machines (including automobiles), and chemical industries, nearly all the leading enterprises followed DuPont's turn toward the new multidivisional form. These industries devoted the most resources to systematic research and development.[258] Institutionalized research brought diversification, which, in turn, brought decentralization of the organizational structure.[259]

The evolution of organizations in other, less diversified industries did not follow the same path.[260] Among the seventy companies studied by Chandler, those that did not adopt the new multidivisional structure by 1960 were concentrated in the metals and materials industries.[261] In the areas of copper and nickel, moreover, major technological and market changes were absent.[262] This permitted the standardization of operations and the routinization of decision-making procedures.[263] In these industries, a centralized structure remained the most efficient one. During this period, the centralized structure was similarly the most efficient in the oil industry, as "the fundamental purpose of [their] structure [was] to unite all activities of the enterprise in meeting changing market demand." More generally, Chandler concludes that "[w]here a company's line of end products was produced by the same manufacturing processes from the same supply of raw materials for a relatively few sets of customers, the centralized, functionally departmentalized form provided that essential coordination."[264] The centralized

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[258] Not coincidentally, according to Chandler, the two major science-based industries were electrical equipment and chemicals:

> They led the way both in the employment of highly skilled non-production workers and the creation of large research and development organizations. In chemicals (SIC 28), scientific personnel in 1921 accounted for 30.4 percent of total scientific personnel employed in the U.S. manufacturing, followed by primary metals with 8.2 percent and electrical equipment with 7.2 percent. By 1946 the figure for chemicals remained almost exactly the same, 30.6 percent. Electrical had risen to 15.5 and metals had dropped to 5.3.

CHANDLER, *supra* note 220, at 80; *see also* Fisk, *supra* note 7, at 490 (arguing that DuPont's attitudes over employee knowledge may be attributable to the nature of the knowledge used in the chemistry-based industry).

[259] CHANDLER, *supra* note 220, at 378 ("Those enterprises whose technological potential rests on modern science, as well as a few food companies, have been able to turn diversification into a highly rational and systematic strategy of growth. Stimulated by institutionalized research, diversification in turn brought decentralization."); *see also id.* at 392–93 ("In the chemical, electrical and electronic, and power machinery industries, the same personnel using much the same facilities with much the same supplies of raw materials were able to develop new engines, new machines, new household appliances, new synthetic fibers, new films or plastics, or new electrical and electronic devices. Since the enterprises in these industries required the highest of technological skills, their administrators invested increasingly larger amounts of their total resources in research and development. Such resources became less and less tied to any specific product line".).

[260] *Id.* at 326–27.

[261] *Id.* at 326.

[262] *Id.* at 329.

[263] *Id.*

[264] *Id.* at 360.

structure therefore fit well in industries that relied on less diversified K_p. In these industries, problems were substantially less complex, requiring less K_i. The standardization of routines enabled an efficient knowledge allocation.

A more recent example of a relatively hierarchical and centralized firm structure is that of IBM in the 1980s and 1990s. While IBM initially defined the path of the computer industry, its business strategy for the personal computer was to develop expertise in mass production.[265] Instead of developing all the required components, IBM decided to purchase most components from outside suppliers in order to rapidly benefit from new inventions and products available on the market.[266] IBM heavily relied on knowledge and technology embedded in products (K_p) that it purchased from suppliers, while still adding their own know-how in organizing the assembly, marketing, and servicing of the personal computers it produced, using K_o and K_i. IBM created a service force to provide national support for its clients and developed a worldwide marketing strategy, spreading its franchised dealers worldwide.[267] Thus focusing on mass production, where profits largely come from increasing returns to scale and scope,[268] IBM also developed a highly centralized organizational structure similar in certain respects to other mass production industries. IBM's Central Management Committee typically made all important decisions.[269]

Chandler argues that as "Compaq and Apple began to build their global enterprises, IBM's Entry Level System Division was becoming integrated back into the long-established, relatively centralized operating structure of one of the world's largest industrial enterprises."[270] IBM's focus on mass production and reliance on K_p, acquired from its suppliers in the form of technology embedded in products, thus made a more centralized, hierarchical structure the most efficient allocation of knowledge and decision rights.

The examples discussed here support the thesis that organizations adapt their structure so as to maximize the efficient management of the knowledge resources that predominate in their production processes. The shift from the C-form to the M-form structure exemplified by DuPont's development, as well as the continued reliance on the C-form structure in certain industries, can be explained by changes in the type of knowledge resources such firms relied upon in their production processes.

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[265] CHANDLER, *supra* note 6, at 136.

[266] *Id*.

[267] *Id*.

[268] *Id*. at 139.

[269] *See, e.g.*, *id.* at 136 ("IBM's Central Management Committee approved Lowe's report, upgraded the task force to a full-scale project development group, appointed Philip 'Don' Estridge its chief, and gave him precisely *one year* to have the product on the market . . . ."); *id.* at 138 ("In 1983 IBM's Central Management Committee created an entirely new Entry Level System Division to manage this explosive growth.").

[270] *Id*. at 146.

D. High-Tech Engineering

The organization of firms engaged in constant innovation is different from that of mass production firms. High-tech firms are concerned with solving problems, which requires high levels of interaction and knowledge exchange.[271] The knowledge necessary for achieving these tasks is mostly embedded in individuals (K_i). To maximize their gains from efficient knowledge allocation, these firms therefore must develop more decentralized firm structures. The availability of legal mechanisms to appropriate K_i will affect the structure of high-tech firms.

1. Restrictive Covenants and the Structure of High-Tech Firms.— One example of the impact of intellectual property regimes on the ownership and decisional structure of firms emerges from a comparative analysis of Silicon Valley's and Massachusetts's high-tech firms. Gilson showed that different patterns of economic development between these high-tech industrial districts are connected to differences in intellectual property regimes in California and Massachusetts.[272] While Massachusetts has a long history of enforcing covenants not to compete and other post-employment restrictions, California's civil code prohibits them.[273]

Gilson argues that the inability to enforce non-compete provisions supported a high velocity labor market in Silicon Valley, in which employees with significant technological expertise could move rapidly between competitor firms or leave their employer to start up their own companies in direct competition with their former employers.[274] Because employers could not prevent employees from appropriating tacit knowledge resources, knowledge spillovers permitted a greater number of smaller firms to specialize in developing new technology.[275]

In contrast, Massachusetts's willingness to enjoin those employees who signed non-compete clauses from competing with their former em-

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[271] *See* Nickerson & Zenger, *supra* note 4, at 621.

[272] *See generally* Gilson, *supra* note 7.

[273] *Id.* at 603.

[274] *Id.* at 595–97; *see also* JOSEPH BLASI ET AL., IN THE COMPANY OF OWNERS (2003). The authors describes how the Nobel Laureate William Schockley left AT&T's Bell Labs to create a semiconductor lab in Palo Alto, only to lose eight of his young researchers, who walked out on him to start their own company, Fairchild Semiconductors. BLASI ET AL., *supra*, at 4–7. Fairchild, in turn "'exploded like a seed pod and scattered the germs of new firms throughout the valley.' By 1970, forty-two new semiconductor companies had been founded by former Fairchild employees or by the firms they had started . . . ." *Id.* at 11 (quoting MICHAEL S. MALONE, THE BIG SCORE: THE BILLION-DOLLAR STORY OF SILICON VALLEY (1985)).

[275] Gilson, *supra* note 7, at 608. Gilson explains the ability of the legal infrastructure to affect the price of knowledge inputs for firms in high-tech industrial districts by promoting Marshallian factor market externalities. *Id.* at 581. Gilson shows the significance that knowledge spillovers played in lowering the price of knowledge inputs for firms in high-tech industrial districts. *Id.*

ployers discouraged employee mobility and knowledge spillovers, leading to the decline of the high-tech industry along Route 128.[276]

While Gilson focuses on explaining legal factors that contributed to the creation of Silicon Valley's regional agglomeration economy, we rely on his analysis to establish the relationship between differences in internal governance structure of high-tech firms in Silicon Valley and Route 128 and the respective legal protections available to employers for binding tacit knowledge embedded in their employees (K_i) to the firm. The traditional, vertically integrated, hierarchical corporate culture in Massachusetts emerged thanks to a legal regime that bound tacit knowledge embedded in employees to the firm. In contrast, a legal regime that did not recognize a firm's property rights over employees' tacit knowledge (K_i) supported a less integrated and less hierarchical firm structure in Silicon Valley.

While there is considerable evidence for the proposition that inter-firm mobility in Silicon Valley is exceptionally high,[277] Silicon Valley's high-tech firms also need to bind knowledge to the firm. Gilson's account of Silicon Valley's knowledge spillovers leaves us with a critical question: If employee mobility was so pervasive, how did the firms survive at all? Key employees must have been retained for significant periods because otherwise firms would simply have collapsed. Lacking certain legal protections (enforcement of covenants not to compete), firms employed alternative devices to bind K_i to the firm. Namely, firms utilized employee stock option plans to bind K_i to the firm. This also encouraged a different type of intra-firm decisional structure and alternative modes of financing.

We argue that a reciprocal relationship exists between non-competes, on the one hand, and compensation—and ultimately ownership—structures, on the other hand. If non-competes cannot be enforced, and firms are unable to appropriate K_i by legal means, then firms will be forced to use alternate organizational strategies to retain employees. Silicon Valley firms responded by offering stock options, a type of equity compensation that is specifically designed to constrain the departure of employees. On the other hand, where noncompetes are enforceable, stock options, or similar equity compensation, are likely to be less common. Stock options are a crucial tool for startups in the high-tech industry to retain knowledgeable employ-

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[276] *Id.* at 591–92 ("In contrast to the Brownian motion of Silicon Valley's high velocity employment, career patterns of employers and managers in Route 128 companies were much more linear. Knowledge workers anticipated long-term employment with a single employer and career development that contemplated rising vertically within an organization, rather than success through lateral movement, as in Silicon Valley. '[T]he practice of leaving a large company to join a small firm or a promising new start-up was virtually unheard of.' Consistent with this pattern, Route 128 gave rise to traditionally vertically integrated companies . . . ." (footnote omitted) (quoting ANNALEE SAXENIAN, REGIONAL ADVANTAGE: CULTURE AND COMPETITION IN SILICON VALLEY AND ROUTE 128, at 63 (1994)).

[277] *See id.* at 590–92.

ees.[278] Their use may constrain *leakage* from firm knowledge resources to other competitors.

Gilson relies on employee mobility and the consequent knowledge spillovers to explain the relative success of Silicon Valley over the performance deterioration on Boston's Route 125.[279] While this should be a relevant factor, we believe that different internal firm organization between the two regions may also have produced significant effects in their performance. We contend that the deterioration of firm performance along Route 128 also provides an example of how internal governance structures affect knowledge production and innovation. According to Saxenian, "Route 128's technology enterprises imitated the structure of the traditional mass production corporation. While Silicon Valley's entrepreneurs rejected the corporate practices of the large, established East Coast producers, the managers along Route 128 saw the same corporations as their models."[280] Relying on interviews with industry executives, Saxenian describes what she calls "hierarchy and formalism" in the companies of Route 128. Managers relied upon formal decision-making processes, conservative workplace procedures and work styles.[281] There was a system of corporate ranks where salaries, benefits, and authority created barriers between functions.[282]

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[278] The "retention" explanation better explains empirical evidence according to Oyer & Schaefer. *See infra* notes 301–305 and accompanying text. The following Associated Press account of the debate on the new FASB requirement that stock options be expensed beginning in 2005 provides an example of this:

> Proponents of mandatory counting of stock options as an expense, including Federal Reserve chairman Alan Greenspan and billionaire investor Warren Buffett, argue that without it investors will continue to get misleading information on companies' financial performance. Awarding options to executives, which can be sold within a short time, gives them an incentive to recklessly pump up the stock price without regard to the company's long-term future, proponents say.
>
> But business interests—especially high-tech companies that are generous campaign donors to both parties—stiffly oppose such a change and their allies in Congress are moving against it. They are predicting dire consequences for high-tech, biotechnology and startup companies, and the U.S. economy, if businesses are required to treat employee stock options as an expense.
>
> "Rank and file employees would be the ones who lost out," Rep. Anna Eshoo, a California Democrat whose district embraces Silicon Valley, testified at a House hearing.
>
> "Broad-based stock option plans have turned employees into corporate partners by tying the interest of the employee together with the company and its shareholders," Eshoo told the House Financial Services subcommittee on capital markets. "Small, entrepreneurial companies with little or no capital use stock options to attract and retain bright and talented employees critical to that company's success."

Possible Stock Option Bans Split Congress, ASSOCIATED PRESS, June 4, 2004, *available at* http://accounting.smartpros.com/x38505.xml.

[279] Gilson, *supra* note 7, at 591–92.

[280] *Id.*; *see* SAXENIAN, *supra* note 89, at 128; *see also id.* at 70 (noting that one senior vice president at Data General (DG) commented: "I constantly study the way larger companies organize themselves looking for ideas. I look at Texas Instruments, at IBM, at ITT, and at GE and GM.").

[281] SAXENIAN, *supra* note 89, at 73–74. "Vertical lines of decision-making authority ensured that flows of information and communications were formal and hierarchically controlled. Corporate Divisions were generally subject to the final authority of a central office." *Id.* at 76.

[282] *Id.* at 77.

Therefore, the development of firm structures in Route 128 towards a mass production oriented structure with centralized decision-making may have constrained knowledge flows and innovation development.

Silicon Valley firms, in contrast, have avoided formal hierarchies, creating organizations with considerably dispersed decision-making and flat authority structures.[283] Decision-making and coordination by managers is reduced in favor of greater self-coordination among experts. Scholars have studied the types of changes in organizational structures that stimulate knowledge creation and knowledge retention.[284] Where scientific knowledge is critical, firms must employ different organizational arrangements.[285] In biotechnology firms, for example, the relation between scientists and universities influenced the structure of biotechnology firms. By permitting scientist–employees to maintain exchanges with universities, new biotechnology firms have created flexible organizations where employees use knowledge in a decentralized way. In order to

> attract and retain such scientists . . . each NBF [New Biotechnology Firm] needed to maintain a "university-like" organizational context as it developed. That is, the NBF's organizational policies had to support both the formation and maintenance of boundary-spanning social network relationships as well as numerous other complementary activities such as rapid publication of research results and freedom of scientific inquiry.[286]

This also accords with the hypotheses that centralized structures tend to be inefficient when production processes heavily depend on knowledge embedded in individuals (K_i). Therefore, the centralized governance structure of firms on Boston's Route 128 may well have affected the knowledge production and the development of new products.

The changes produced in ownership structure due to the need to bind tacit knowledge to the firm thus altered not only decisional hierarchies, but also information flows within the firm. It furthered bottom-up decision-making and innovation, frequently blurring the lines between management and lower level employees.[287] Such changes, in turn, promoted the creation

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[283] *Id*. at 143.

[284] *See, e.g.*, Tomas Hellström, Ulf Malmquist & John Mikaelsson, *Decentralizing Knowledge: Managing Knowledge Work in a Software Engineering Firm*, 12 J. OF HIGH TECH. MGMT. RES. 25 (2001) (arguing against top-down management decisions in software engineering firms).

[285] Julia Porter Liebeskind et. al., *Social Networks, Learning and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms*, 7 ORG. SCI. 428, 439 (1996) (internal quotations omitted).

[286] *Id*. (arguing that intellectual resources are characterized by "severe immobility," because a few star researchers have made commercially valuable discoveries, and many of them work at universities).

[287] BLASI ET AL., *supra* note 274, at 40, 45. Blasi describes such high-tech firm culture as follows:

> [E]mployees come to see taking important issues right to the door of management as appropriate, even to the door of the top executive. In fact, some companies already have a term for walking problems and issues up to management. They call it escalation, as in "She felt she had to escalate the issue, to bring it to the attention of the decision-maker who could sort the problem out."
>
> Sometimes, if an issue is important enough and involves the broadest interests of the company, an employee may even take it directly to the CEO.

of fertile environments for knowledge production in an industry that required constant and rapid innovation, subject to the attendant knowledge hazards. Apart from retaining employees, stock options also served to avoid the knowledge hazard of *hoarding*, i.e., the failure on the part of an employee to fully disclose his knowledge to others at the company. Finally, giving employees a greater stake and voice in the management of the firm served as an effective means of monitoring the workplace.[288] Employee stock options are widely regarded as an essential component to the partnership-style organization that characterizes these firms.

2. Employee Stock Option Plans As an Alternative Means to Binding Knowledge to the Firm.—Three theories have been offered in corporations theory to explain the use of stock options in employee and executive compensation.

The standard view is that option grants contain agency costs by aligning the incentives of managers (the agents) with those of shareholders (the principals). This view is reflected in the remark by Hall that stock options are "the best compensation mechanism we have" for "getting managers to act in ways that ensure the long-term success of their companies."[289] Compensation experts and business scholars in the nineties advocated granting stock options packages to executives so as to align remuneration with corporate performance.[290]

In the wake of recent executive pay scandals, however, this use of stock options has been severely criticized, and the agency cost view has been reconsidered.[291] Bebchuk, Fried and Walker have thus offered a sec-

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Id. at 45.

[288] BLASI ET. AL., *supra* note 274, at 43. Blasi, Kruse, and Bernstein provide an anecdotal account on this point:

> For example, [at] a Palo Alto, California, company named Tibco Software Incorporated, a thirty-something events planner named Jennifer told us: "When you have ownership in the company, you . . . watch costs. We're going to Hawaii next week for a sales trip. Well, one person didn't get their travel [arranged] . . . so I called him and said: 'What are you doing, book your travel, if you wait your ticket is going to be so much higher.' You're constantly watching that stuff when you're an owner."

Id.

[289] Brian Hall, *What You Need to Know About Stock Options*, HARV. BUS. REV., Mar.–Apr. 2000, at 121, 122.

[290] *See, e.g.*, Michael Jensen, *The Modern Industrial Revolution, Exit, and the Failure of Internal Control Systems*, 6 J. APPLIED CORP. FIN. 19 (1994); Michael C. Jensen et al., *Remuneration: Where We've Been, How We Got to Here, What Are the Problems, and How to Fix Them* 28 (Harvard NOM Working Paper No. 04-28; ECGI–Finance Working Paper No. 44/2004), *available at* http://ssrn.com/abstract=561305.

[291] *See generally* DONALD P. DELVES, STOCK OPTIONS AND THE NEW RULES OF CORPORATE ACCOUNTABILITY 39 (2004) (noting that many argued that the spread of stock options "had the effect of transferring a growing portion of the future value of the company from the hands of shareholders into the hands of employees and managers"); Lucian Arye Bebchuk, Jesse M. Fried & David I. Walker, *Managerial Power and Rent Extraction in the Design of Executive Compensation*, 69 U. CHI. L. REV. 751 (2002).

ond theory that attributes the widespread distribution of stock options, quite simply, to managerial power. According to Bebchuck et al., stock options are awarded, because executives have the ability to influence their own compensation schemes, and use the mechanism to engage in rent seeking.[292] The "managerial power" thesis, however, fails to explain why executives did not merely award options to themselves, but also approved broad-based employee stock options plans. The theory simply does not address this broader use of stock options awarded to non-executive employees who were not in a position to engage in rent-seeking behavior.[293]

To explain the more broad-based distribution of stock options, Murphy has offered yet another theory, which is called the "perceived-cost" theory. On this view, companies erroneously perceived stock options as relatively low-cost compensation mechanisms, because options could be granted without any cash outlay, and, until recently, without incurring certain accounting charges.[294] The "perceived-cost" view of stock options would thus account for the proliferation of broad options plans that are difficult to explain on the basis of competing economic theories, including that of Bebchuk et al.

These arguments are unconvincing. Stock options critics typically fail to distinguish the use of stock options in S&P 500 Industrials, on the one hand, and in high-tech companies and other skill-based firms, on the other hand.[295] Companies in skill-based industries, such as new economy firms, are significantly more likely to have broad-based stock options plans than other firms.[296] One study based on a benchmark group of the top-100 largest internet-based companies by revenue showed that 98 "of these companies handed out options to at least 51 percent of their employees, compared with just six percent in a group of comparably sized, mostly non-tech com-

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[292] Bebchuk, Fried & Walker, *supra* note 291, at 754.

[293] This criticism has been made before in Kevin J. Murphy, *Explaining Executive Compensation: Managerial Power Versus the Perceived Cost of Stock Options*, 69 U. CHI. L. REV. 847, 857 (2002).

[294] *Id*. at 859–60. FAS 123(R), effective as of July 2005 for most companies, required the expensing of stock options based on fair value accounting. *See* Financial Accounting Standards Board of the Financial Accounting Foundation, *Statement of Financial Accounting Standards No. 123 (revised): Share-Based Payment*, Dec. 2004 (No. 263-C), at ii, *available at* www.fasb.org/pdf/fas123r.pdf.

[295] Murphy, *supra* note 293, at 850.

[296] Paul Oyer & Scott Schaefer, *Why Do Some Firms Give Stock Options to All Employees?: An Empirical Examination of Alternative Theories*, 76 J. FIN. ECON. 99, 128 (2005). The authors report that new economy firms (that manufacture computers, semiconductors, telephone equipment, create software, or computer-related products) are 33% more likely to have broad-based stock option plans than standard firms. *Id.*; *see also* DELVES, *supra* note 291, at 39. There is a higher percentage of outstanding stock devoted to stock option plans in the high-tech industry, as compared with general industry companies who typically restrict stock options to executives:

> the percentage of outstanding stock devoted to stock option plans increased dramatically, rising from 3 to 5 percent in 1990 to 12 to 15 percent among general industry companies in 2001. In high-technology companies the average is much higher—18 to 25 percent, with some companies as high as 30 to 40 percent.

Id.

panies traded on the New York Stock Exchange."[297] In another study of 756 firms, most stock options were given to employees below the top executive level.[298]

Both the managerial power and the perceived-cost explanations are largely inconsistent with the empirical evidence on the distribution of stock options plans. The managerial power explanation cannot explain the distribution of stock options to non-executives at all. Moreover, considering that all companies have been subjected to the same accounting regulation, the perceived-cost view does not explain why high-tech firms have consistently granted stock options to non-executive employees while other firms rarely have. The perceived-cost explanation cannot explain why some firms would differently perceive precisely the same costs. The patterns of stock options distribution across different industries would have to be similar in order for the perceived-cost explanation to make sense. But this is not the case.

The data suggests to us that stock options for employees in high-tech firms serve a very different function[299] than stock options for executives in other sectors,[300] namely to bind individuals with knowledge critical to the production process to the firm. If the purpose is retention of employees with knowledge and skills that are critical to the firm, then it follows that broad-based stock option plans may serve shareholder interests in industries that rely heavily on K_i, but less so in industries that rely heavily on K_p, or a combination of K_p and K_o.

Our view is corroborated by a recent empirical study. Oyer and Schaefer investigate alternative explanations for stock option compensation in the high-tech sector and reject the standard agency cost explanation. The study sample encompasses firms that offer broad-based stock option plans to mid-level executives. The study analyzes three alternative explanations for stock options:

(1) Agency Theory Explanation. Stock options provide incentives to employees. They attach the employee's wealth to the value of the firm in order to overcome agency problems and motivate the employee to perform according to the firm's interest.

(2) Sorting Explanation. Stock options induce employees to sort based on their beliefs regarding firm's prospects. Options attract optimistic employees, willing to take the risk, and reduce overall compensation costs for the firm.

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[297] Dan Reed, *Stock Options Benefited Workers: Research Shows Average of $425,000*, SAN JOSE MERCURY NEWS, Jan. 10, 2003, at 1A, 6A.

[298] *See* John E. Core & Wayne R. Guay, *Stock Option Plans for Non-Executive Employees*, 61 J. FIN. ECON. 253, 265 (2001).

[299] *See* BLASI, *supra* note 274, at 61.

[300] *Id.*

(3) Retention Explanation. Stock options help firms retain employees as a form of deferred compensation. They have a vesting period attached that increases the costs to employees of departing from the firm.[301]

Oyer and Schaefer reject the incentives-based (agency-cost) explanation for broad-based stock option plans because the risk premium stemming from option-based pay dwarfs the cost to the employee of the associated increase in effort.[302] If effort were contractible, the employee would be willing to exert additional effort for a payment dramatically smaller than the risk costs imposed on the firm by providing stock options.[303] Given the existence of other means to evaluate subjective performance and to reward employees for the value they create, the authors conclude that stock options are a very inefficient means to provide incentive to employees.[304]

Interestingly, the authors regard sorting or retention first-order determinants of the decision to adopt a broad-based stock option plan. They believe that "firms that adopt broad option plans are those for which the returns to cost effectively attracting and retaining employees are particularly high."[305] Industry leaders confirm that, in an environment of intensive competition for highly mobile employees, such as Silicon Valley, stock options "act[ed] like financial magnets, binding employees to their companies for the long term."[306] Cisco's CEO, John Chambers, recognized that "our industry is not like the banking industry where you are acquiring branch banks and customers. In our industry, you are acquiring people. And if you don't keep those people, you have made a terrible, terrible investment."[307] Chambers clearly understood the shift from the output of machines (our K_p) as the "fundamental driver of competitive advantage," to the significance of

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[301] Oyer & Schaefer, *supra* note 296, at 107–10.

[302] *Id*. at 118–19.

[303] *See id.* at 118.

[304] *Id.* at 131. Stock-options-as-incentives could perhaps be a sensible explanation under a very limited set of circumstances, where employees have the power to take actions that have large value implications for the firm, at very limited cost to the employees taking such actions, and where it is extremely difficult for firms to monitor such employees. *Id*. at 119.

[305] *Id*. at 132. In order for the sorting explanation to make sense, it must be the case that employees strictly prefer the observed salary plus options to an all-cash package. *Id*. at 119. At an expected return of 25% annual stock appreciation, the employees at nearly all the firms of the sample value their options packages significantly more than they would value a comparable all-cash package. *Id*. at 122. Authors believe this explanation to be significant.

[306] BLASI, *supra* note 274, at 42; *see also* DELVES, *supra* note 291, at 40 ("Like many other technology companies, the chip maker [Intel] has used options heavily as a recruiting and retention tool." (citing *The Wall Street Journal*)).

[307] DELVES, *supra* note 291, at 54. CISCO's extensive stock option plans were based on the understanding that acquiring and retaining human capital was key to success in the high-tech industry: "Each year [Cisco] employees have the right to purchase $25,000 worth of company stock at 15 percent off the opening or closing price of the previous six months, whichever is lower." BLASI, *supra* note 274, at 53. In stark contrast to the confinement of stock options to executives in the more traditional public corporations, Cisco's stock options plan typically gives non-executives more than 90% of all options handed out. *Id.* at 53–54.

"intangible ideas—the output of people, in an economic sense" (our K_i) in the internet economy.[308]

Murphy has predicted that an accounting charge would halt the proliferation of broad-based stock option plans, causing companies to limit grants to top level executives.[309] Our view, however, suggests that high-tech firms will not ban stock options altogether after the passing of FASB's expensing rule. While changes to the accounting rules may diminish the incentives for firms to adopt broad stock option plans as a compensation mechanism,[310] if stock options are an efficient way of binding K_i, we expect that a significant number of high-tech firms will still continue to use them or turn to alternate mechanisms of deferred compensation.[311]

Indeed stock options appear to remain a popular equity compensation vehicle.[312] Research analysts point out that the percentage of companies offering nonqualified or qualified stock options has dropped by 11 points after the options-expensing rules under FAS 123(R) took effect—which is far from a complete departure from their use.[313] According to surveys conducted among energy companies, "attracting and retaining top talent appears to outweigh the cost of adapting to new accounting and tax requirements."[314]

Our theory explains the use of special compensation packages for nonmanagerial employees by knowledge-intensive firms. Because stock options are used to bind critical productive knowledge, we would expect to see alternative mechanisms for retaining key employees, if companies chose

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[308] BLASI, *supra* note 274, at 37 (quoting speech of John T. Chambers).

[309] Murphy, *supra* note 293, at 867–68.

[310] FASB requires that companies expense stock options awards and take a charge against earnings for the "fair value" of the options granted as of June or December 2005 (depending on the type of company and filing), where previously options awarded at fair market value under APB No. 25 were "off the books," so to speak, and did not require companies to recognize any compensation expense. Statement of Financial Accounting Standards No. 123, *supra* note 294, at ii–iv, vi (discussing key provisions and changes in the accounting rules, and relevant effective dates). Representatives from Silicon Valley firms strongly argued that the new accounting rules would harm their ability to recruit and retain employees. *See supra* note 297.

[311] *See also* James B. Rebitzer & Lowell J. Taylor, *When Knowledge Is an Asset: Explaining the Organizational Structure of Large Law Firms* 27–28 (Inst. Study Lab. (IZA) Discussion Series, Paper No. 2353, October 2006), *available at* http://ssrn.com/abstract=3003.

> In high technology firms, many of the key assets of the enterprise are bound up in the brains of crucial employees. Property rights to some of these intellectual assets can be secured through patents or copyrights. When adequate control *cannot* be attained through intellectual property rights, one should expect to see innovations in the employment relationship that reduce the firm's vulnerability to losing valuable assets. In some instances, high technology companies reduce the incentive of key "knowledge workers" to leave through the use of stock options and other forms of deferred compensation that become dramatically less valuable when the employee exits the firm.

Id. at 28.

[312] *Companies Turn to Restricted, Performance-Based Stock*, WORKSPAN, May 2006, at 17.

[313] *Id*.

[314] *Id*. at 56.

to ban stock options altogether for reasons unrelated to retention. The use of restricted stock, which has recently been increasing, might be viewed as an attempt to replace stock options, while still satisfying the goal of retention.[315] We expect that companies will continue to use some form of equity compensation as a means to retain critical employees who are not officers or executives in knowledge intensive industries.[316]

E. Law Firms

Several commentators have argued that human capital is the most important asset of law firms.[317] Based on our theory, law firm organization can be explained as a response to achieving an efficient allocation of K_i, or human knowledge. Despite the seeming recognition of the importance of knowledge, the literature has so far underestimated the impact of knowledge allocation on the structure of law firms.[318]

Gilson and Mnookin's portfolio and agency theory approach to law firm structure provides an example. Gilson and Mnookin argue that diversification provides an explanation for the existence and structure of large law firms. On their theory, law firms eliminate unsystematic risk by diversifying the areas in which they provide legal services.[319] From this perspective, when an individual lawyer is admitted to partnership he exchanges his human capital for participation in a diversified portfolio with respect to the personal characteristics of lawyers and their expertise in the firm.[320] The diversification is achieved by sharing the future income of the firm equally

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[315] *See Companies Turn to Restricted, Performance-Based Stock*, *supra* note 312, at 17; Dina Pyron, *Pay for Performance*, OIL & GAS INVESTOR, Oct. 2005, at 55, 58.

[316] Pyron, *supra* note 315, at 58 ("[I]t is clear that energy companies are far from taking an automatic stance to reduce equity compensation in reaction to regulatory changes. Indeed, such are the competitive dynamics of their international human-resource climate that as many companies say they will be increasing the reach of equity compensation worldwide in the future as say they have plans to reduce it.").

[317] *See, e.g.*, Ronald J. Gilson & Robert H. Mnookin, *Sharing Among the Human Capitalists: An Economic Inquiry into the Corporate Law Firm and How Partners Split Profits*, 37 STAN. L. REV. 313, 324 (1985) [hereinafter Gilson & Mnookin, *Sharing Among Human Capitalists*]; Ronald J. Gilson & Robert H. Mnookin, *Coming of Age in a Corporate Law Firm: The Economics of Associate Career Patterns*, 41 STAN. L. REV. 567, 570 (1989) [hereinafter Gilson & Mnookin, *Coming of Age*].

[318] *See* Gilson & Mnookin, *Sharing Among Human Capitalists*, *supra* note 317; Gilson & Mnookin, *Coming of Age*, *supra* note 317.

[319] *See* Gilson & Mnookin, *Sharing Among Human Capitalists*, *supra* note 317, at 329. The authors argue that a portfolio composed of a sufficient number of assets will neutralize the effects of an event that lowers the value of one asset by a favorable impact of the same event on the value of other assets. *Id.* at 322. If the portfolio is fully diversified, it will not be subject to unsystematic risk. *Id.* at 322–23. Therefore, a law firm that can diversify the areas in which it provides legal services can reduce its exposure to unsystematic risk. *Id.* at 326. Equity owners of a law firm thus can achieve gains from the diversification of their human capital, just as securities investors can achieve gains from the diversification of their securities portfolio.

[320] *Id.* at 342.

between the partners according to a seniority system.[321] Gilson and Mnookin argue that law firm organization is shaped by the effort to diversify and the difficulty of doing so.[322]

Gilson and Mnookin further posit that "it is striking just how well diversified the portfolios of established firms are,"[323] although they do not provide evidence for this claim. Whether law firms are really diversified is a question that can be answered only by the empirical evidence. In a recent empirical study, sampling all law offices in the United States, Garicano and Hubbard analyze confidential office-level data from the 1992 Census of Service on the hierarchical organization of law firms and on field-specialization by attorneys and firms. Their results show that "[l]awyers are more likely to work at the same firm with other lawyers in the same field than in any other field."[324]

Garicano and Hubbard find evidence that a firm's boundaries narrow as lawyers specialize in so-called ex-post fields (resolving disputes).[325] This evidence is contrary to Gilson and Mnookin's theory of risk-avoidance through diversification because Garicano and Hubbard's study suggests that the typical law firm is an imperfectly diversified portfolio at best.[326] Law firms may diversify across specializations within a given legal field, for instance, in the area of business law. Even in business law, however, firms specialize in either ex-ante or ex-post legal services, that is, in either transactional or litigation, but not both.[327] A firm that provides services in securities law for the purposes of performing an IPO is less likely to also provide securities litigation services for the same client than a different firm. This decreases the explanatory power of the diversification theory,

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[321] *See id.* at 339–43.

[322] *See id.* at 352–53. Gilson and Mnookin argue that

> the creation of a full-service law firm—an agreement among lawyers that each will make human capital investments in different specialties and that the return to those investments will be shared on a predetermined basis rather than in accordance with actual outcomes—can be understood as an institutional innovation that allows lawyers to take advantage of gains from diversification.

Id. at 329. The authors give an example of a securities and a bankruptcy lawyer, arguing that when there is a bear market the lack of business in the securities area will be counterbalanced by the increase of work load in the bankruptcy area and vice-versa. *Id*. at 327–39.

[323] *Id.* at 342.

[324] Luis Garicano & Thomas N. Hubbard, *Specialization, Firms, and Markets: The Division of Labor Within and Between Law Firms* 2 (U. Chi. John M. Olin Law & Econ. Working Paper Series, Paper No. 213, 2003), *available at* http://ssrn.com/abstract=404280.

[325] *Id*. ("We also find that lawyers in ex ante fields that serve business demands tend to work at the same firm as lawyers in any of the ex ante business fields, and tend not to work at the same firm as lawyers in either ex post business fields or fields that serve individual demands. For example, specialists in corporate law tend to work at the same firm as specialists in real estate law, but not specialists in insurance or criminal law.").

[326] *See id*. at 4–5.

[327] *See id.* at 27–28. Specialists in ex ante business law tend to work in the same firm as one another. *Id*. at 2. According to the authors' definition, business law includes banking, corporate, governmental, environmental, tax and real estate law. *See id.* at tbl. 2.

because a well-diversified firm would want to offer the right balance between ex-ante and ex-post legal services. In times of recession, litigation tends to be more profitable than consulting and other ex-ante transaction fields. One would thus expect an optimum mix between ex-ante and ex-post areas if law firms aimed at portfolio-type diversification. But such a business mix is not borne out by the average practice.

Instead, the division between ex-ante and ex-post legal services points to an organizational strategy based on knowledge specialization. This is also consistent with the existence of law firms specializing in different, very specialized types of litigation requiring the mastery of a body of legal knowledge and interactive skills (litigator vs. negotiator or transactional vs. regulatory compliance counselor).

The data also reveal that specialists in patent law tend not to work together with specialists in any other field.[328] Instead they work in firms that specialize solely in intellectual property. Garicano and Hubbard conclude that

> [b]roadly, these patterns provide no support for the hypothesis that law firms' field boundaries strongly reflect the risk-sharing benefits of revenue-sharing arrangements. Lawyers in the same field or fields where demands are closely related tend to work at the same firm more than lawyers in fields where demands are less closely related.[329]

Portfolio theory, therefore, may provide an explanation—albeit a very incomplete explanation—for the organization of a small number of large law firms that service large corporations. But it does not explain why the average law firm is specialized rather than diversified.

An additional piece of data derived from the research conducted by Garicano and Hubbard is revealing. According to the study, 28% of law firms specialize in a single field.[330] The fact that such a significant number of law firms operate in one single area clearly points to specialization as an important factor in the structure of law firms. The empirical evidence available on the boundaries of law firms suggests a knowledge-based explanation. Garicano and Hubbard advance a knowledge-sharing explanation of law firm structure and develop a model of hierarchy in which increasing returns are associated with the utilization of knowledge because of gains in knowledge specialization. Therefore, specialization and hierarchical organization reflect an optimal use of costly knowledge resources.[331]

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[328] *Id*. at 27. The only other exception found by Garicano and Hubbard is that specialists in probate law—which the authors identify as an individual field rather than a business field—tend to work in the same firm with ex ante business specialists. *Id.*

[329] *Id*.

[330] *Id*. at 14.

[331] *See* Luis Garicano & Thomas N. Hubbard, *Hierarchies, Specialization, and the Utilization of Knowledge: Theory and Evidence from the Legal Services Industry* 2 (U. Chi. John M. Olin Law & Econ. Working Paper Series, Paper No. 214, 2004), *available at* http://ssrn.com/abstract=533183 ("Hierarchies enable individuals to increase the utilization of expert knowledge by shielding experts from

Lawyers are more likely to work together within the same firm when knowledge sharing—in the form of collaboration or referrals—provides added value.[332] When knowledge sharing is less valuable, lawyers should opt to work separately and cooperate where desirable through market exchanges.

1. A Knowledge-Based View of the Organizational Structure of Law Firms.—We have hypothesized that when production relies more on K_i, the organizational structure of a firm will be less hierarchical. Because law firms rely primarily on human capital, or K_i, we expect that law firms will have flatter hierarchies compared to firms in other industries.

Law firms that follow this approach have traditionally had partners and associates,[333] a distinction that marks the attorney's position in the firm hierarchy relative to the distribution of knowledge and experience, and corresponds to a division of labor.[334] Partners direct, guide, coordinate, train, and monitor the quality of associates' work. Partners exert decision-making authority in law firm matters and get (most of) the residual claims. Associates engage in tasks requiring less knowledge and experience that are also more routine.[335] Further, the associateship functions as a kind of apprenticeship.[336] At the time of the initial hiring decision, the law firm does not yet foresee which associates will develop enough knowledge and personal attributes that the firm requires in a partner.[337] The associate's legal skills and ability to deal with existing clients and attract new ones is judged during the associateship period to determine whether he or she has the qualities necessary to become a partner. In our framework, the associate thus has K_i– or K_i, whereas the partner, who is more knowledgeable, has K_i+.

While law firm hierarchies are flat when compared to firms in other industries, there is nevertheless a hierarchy based on observed differences in K_i among the various knowledge workers in the firm, as our theory predicts. Because the firm must allocate knowledge resources efficiently, it will give decision-making authority to the partner who is more knowledgeable, able to make better decisions, and to coordinate the work of associates. When associates gain knowledge, their decision-making authority increases and they are gradually less supervised, afforded greater autonomy, and are charged with supervising the work of lower-level associates.

The data supports our theory that firm structure is influenced by the efficient allocation of knowledge resources. According to Garicano and

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simple problems and allowing them to specialize in problems they have a comparative advantage in addressing.").

[332] *See id.* at 9.

[333] *See* Gilson & Mnookin, *Coming of Age*, *supra* note 317, at 567.

[334] *See* Garicano & Hubbard, *supra* note 331, at 5.

[335] *See* Gilson & Mnookin, *Sharing Among Human Capitalists*, *supra* note 317, at 358.

[336] *See* Gilson & Mnookin, *Coming of Age*, *supra* note 317, at 572–74.

[337] *Id.* at 572.

Hubbard's data, 73% of law offices have no associates. These "non-hierarchies" include single-lawyer offices and offices where there are several lawyer partners.[338] The authors report that associate–partner ratios are low, even when the analysis is restricted to law firms that serve primarily business clients and have at least one associate.[339] Across all firms, 19% of all law offices have associate–partner ratios greater than zero and less than or equal to one.[340] Only 8% of all law offices have associate–partner ratios greater than one.[341] This shows that law firms have very flat hierarchies, a consequence that we infer from the predominant type of knowledge used in its production process, that is, knowledge embedded in individuals (K_i).

An interesting finding from this vantage point is that a law firm's level of hierarchy correlates with the degree to which its lawyers are field-specialized.[342] In other words, hierarchical organization reflects the human capital that lawyers bring to the table. The share of lawyers who field-specialize is directly proportional to the associate–partner ratio of the firm and tends to be higher at offices where the associate–partner ratio is greater. According to the data, it increases from 45% at offices where the associate–partner ratio is zero to over 80% at offices where the ratio is at least one.[343] When the lawyer specializes, she is expected to be more knowledgeable in her field of expertise, an important condition for her to be a partner held responsible for the quality of the service provided. Augmenting hierarchical levels is thus explained by the increase in disparity of knowledge that individuals possess.

Even within the flatter hierarchies of law firms we can identify gradations of knowledge among employees and a corresponding hierarchy of decision-making authority.[344] Accordingly, our typology accommodates the fact that law firms, which rely predominantly on K_i, have hierarchies by distinguishing among individuals with varying degrees of technical or context specific knowledge (K_i–, K_i, and K_i+). When applying the principle of efficient knowledge allocation, the most knowledgeable employees (K_i+) should be in top positions of a firm's hierarchy, and less knowledgeable employees (K_i and K_i–) at lower levels. Individuals with greater expertise will engage in significant "knowledge substitution," guiding the behavior and decision-making of those less knowledgeable, while conserving their

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[338] Garicano & Hubbard, *supra* note 331, at 5.

[339] *Id.* at 6.

[340] *Id*.

[341] *Id*.

[342] *Id.* Field-specialization occurs when a lawyer works primarily in one of the thirteen fields defined by the Census (for example, corporate, tax, or probate law). *Id.*

[343] *Id.*

[344] *See* Gilson & Mnookin, *Sharing Among Human Capitalists*, *supra* note 317, at 319.

own time by allowing those less knowledgeable to make lesser judgments without the involvement of more senior personnel.[345]

To summarize, the "Cravath system" gives greater decision-making authority and greater residual claims to the lawyers with greater knowledge and experience. The partners retain control over client relationships, concentrate on doing the most complex work, and train, supervise and monitor associates. Partners have a surplus of human capital (K_i) that they lend out and monitor—so-called human capital sharing. Younger associates borrow knowledge distributed by senior partners until they develop their own professional expertise. Partners who concentrate greater knowledge in their hands are the residual claimants of the partnership. In contrast, associate lawyers with less knowledge tend to receive a fixed salary.[346]

More associates are hired than can be promoted to the partnership, and many associates will be dismissed before they acquire sufficient client knowledge to "grab and leave." Rebitzer and Taylor argue that organizational features such as the use of "up-or-out" promotion contests and the practice of having winners become residual claimants in the firm, emerge as a consequence of the knowledge-intensive setting in which these firms operate.[347] The winners of the promotion contest become partners, with residual claims, because this solves the problem of binding knowledge assets to the firm.[348] Associates tend to leave the firm as soon as they find out they will not be promoted, and law firms even help their associates find new jobs.

Intellectual property rights do not permit that law firms bind the knowledge of lawyers to their structure. To cope with this legal constraint, law firms therefore design specific organizational strategies. Associates tend to be promoted into the partnership or dismissed in order to avoid their

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[345] Another example of flatter hierarchies would be universities. The distinction between tenure and untenured professors is also based on the amount of knowledge and personal experience that professors have. In order to manage this knowledge in an efficient way, universities shaped their organizational structure by creating a system in which tenured professors are guaranteed stability through the privilege of tenure as well as greater decision rights than untenured professors.

[346] *See* Gilson & Mnookin, *Coming of Age*, *supra* note 317, at 572–74.

[347] Rebitzer & Taylor, *supra* note 311, at 3 ("Attorneys are 'knowledge workers,' who differ from other employees because they essentially carry around key firm assets in their brains. The knowledge assets these lawyers control—an understanding of the needs and interests of clients—are obviously of greatest value when used with specific clients. This specificity gives individual attorneys considerable leverage over their employers. By threatening to 'grab and leave' with an important client, attorneys can leverage an increased share of their firm's revenues. The up-or-out partnership system found in large law firms has evolved over time as a workable resolution to this particular problem. By forming partnerships and firing experienced attorneys who are not promoted to partnership positions, law firms limit the opportunity for experienced attorneys to grab and leave with the firm's valuable clients. Grabbing and leaving is more important in legal partnerships than in conventional firms because law firms cannot readily establish property rights over the knowledge essential for serving particular clients.").

[348] *Id.* at 3, 5 (stating that their model firm's "net worth is tied to the knowledge of its senior employees").

acquisition of a key knowledge asset, the long-term client relationship. This practice reduces the risk of leakage of client knowledge. However, if the firm can limit direct contact between clients and associates (and limit associate work experience) by restricting their work (and learning) to small pieces of more complex operations, the length of the associate period can be increased. If client contact could be eliminated entirely, the firm could employ associates indefinitely.[349]

Another organizational feature explained by a knowledge efficient allocation perspective is the law firm's sharing model of compensation. Gilson and Mnookin defended the view that the sharing model serves the purposes of risk-sharing by splitting the profits on a predetermined basis to allow attorneys to take advantage of a "diversified portfolio" in their law firm's equity.[350] Instead, knowledge considerations suggest that profits are split to provide attorneys with the necessary incentives to pass cases or clients to other attorneys within the firm who are more knowledgeable in the areas the client requires, or, alternately, to consult with other more knowledgeable attorneys in the firm on such cases and clients. Moreover, other attorneys in the firm will be more willing to devote their time and efforts to applying their knowledge in assisting another partner's clients where profits are split. This arrangement thus enhances efficient knowledge allocation within the firm in that each lawyer will have the proper incentives to perform those services for which she is most qualified. Otherwise, lawyers would have incentives to supply services to clients regardless of expertise.

2. The Changing Organizational Structure of Law Firms.—The structure of the law firm has been increasingly changing during the past thirty years. Law firm structure was characterized by only two categories of attorneys—partners and associates—but is expanding to include new non-equity partners,[351] special counsel, permanent or superannuated associates, staff attorneys, and contract attorneys. The expanding levels of personnel is further evidenced by the increase in different levels of paralegals and other layers of staff—such as word processors, IT personnel, practice support—that have increasingly augmented large firm practice.[352] These new professionals add new layers of hierarchy to the organizational structure of law firms.

Feinberg has found that the substitutability between paralegals and associate lawyers has not increased over time.[353] According to this evidence,

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[349] *Id.* at 19.

[350] *See* Gilson & Mnookin, *Sharing Among Human Capitalists*, *supra* note 317, at 341–43.

[351] Gilson & Mnookin, *Coming of Age*, *supra* note 317, at 567.

[352] Robert M. Feinberg, *Paralegals and Associate Lawyers: Substitutability Within the Law Firm, 1977–87*, 76 REV. ECON. & STAT. 367, 367 (1994) (reporting that since the mid-1970s there was a development of a paralegal career and that employment in taxable legal services increased from about 14,000 in 1972 to more than 100,000 in 1987).

[353] *Id.* at 371.

the number of associates has not decreased because of the increasing number of paralegals. Therefore, associates are not being replaced by paralegals, but there has been an increasing specialization of work among legal professionals,[354] and a corresponding expansion of law firm hierarchy.

What is striking is that this expansion of law firm hierarchy is occurring in conjunction with the increasing reliance of law firms on a different knowledge type—that of knowledge embedded in products and machines (K_p) capable of being claimed or held by the firm as a kind of property. Law firms increasingly store knowledge in precedent information systems, client databases, and other sophisticated knowledge management systems. Thousands of drafts, contracts, legal opinions, briefs and client-specific data are stored in the larger law firms' proprietary electronic storage systems. "Knowledge management" departments have emerged to maintain internal databases and to train the professionals who will operate and use them. The large law firms have transformed their knowledge base from knowledge embedded almost exclusively in individuals (K_i) to knowledge embedded increasingly in information systems (K_p).

While record-keeping devices have always been used in one form or another, internal precedent systems and other database resources separate knowledge from the attorney. Knowledge is thereby standardized and made available to the next associate who can take up the case two years down the line to perform a particular task—whether by writing a brief, summarizing a past transaction, or preparing a term sheet based on client precedents—without prior experience in a particular case, or even with a functional knowledge of firm style or format. All the associate needs to know is how to use the precedent system in order to apply more general professional knowledge to the replication of a typical firm product by following the example. This dramatically reduces the need for partner involvement in the initial stages of any project, as well as at later stages that can be sufficiently routinized and standardized. Separating knowledge through codification and standardization thus turns legal work into more of a production routine, and permits partners to assume a more managerial role with regard to their associates.

According to our theory, when K_p's importance increases in the productive process, the organizational structure of the firm will become more centralized, creating steeper decisional hierarchies. This shift from K_i to K_p has indeed brought about a corresponding change in law firm decision-making structures. In the new corporate law firm, low-level attorneys become more replaceable, as they increasingly rely on K_p to do their tasks. Thus large firms now hire large numbers of staff attorneys who, for example, organize documents and databases, retrieve documents, and help prepare document reviews. Staff attorneys can attend depositions, take notes, and record information where necessary. But they perform only a limited

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[354] *See id.* at 371.

number of specific routine tasks and exercise judgment only within limited parameters. Staff attorneys are directed by partners and associates or senior staff attorneys (who in turn are directed by partners) and tend to have no client contact. In order to provide the client with competitively priced services while maintaining high quality, large corporate law firms thus employ professional staff attorneys as assistants to associates in order to lower the cost of legal services by conserving more expensive associate and partner time. Staff attorneys are not on a partnership track, so they provide the added benefit of a potentially much more long-term relationship without the need to share residuals.

In addition to staff attorneys, large law firms also hire so-called contract attorneys to fill fluctuating demand for legal work that is more mechanical than even the work done by staff attorneys. In the litigation setting, for example, contract attorneys work as document "coders" to assist in processing the mammoth document productions characteristic of large, complex, multi-party commercial disputes. Such coders receive specific instructions on identifying and coding documents in order to load them onto a database and render them searchable. Such work is mechanical work done at a computer terminal and controlled by software templates that permit only certain types of inputs.

Therefore, the hierarchy within law firms is becoming steeper and more centralized where the ratio between partners and other professionals (including staff lawyers, contract attorneys, and paralegals) is higher than in the past. The embedding of knowledge in information systems (K_p) has made many of these professionals who now perform more standardized routine work replaceable, increasing the similarities between the structure of contemporary law firms and mass production firms. It is in this context that many of the large law firms have changed their business form and have moved from a partnership structure to the limited liability corporation form.

F. The Implications of Knowledge Transfer for the Choice of Business Transactions

A variety of motivations have been recognized for mergers and acquisitions, including operational and financial synergy, portfolio diversification, and other strategies based on finance theory.[355] But traditional mergers and acquisitions theory does not make knowledge considerations central.[356] A knowledge based perspective, we argue, can provide important insights

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[355] RONALD GILSON & BERNARD S. BLACK, THE LAW AND FINANCE OF CORPORATE ACQUISITIONS 259 (2d ed. 1995) (discussing the theoretical sources of operating synergies such as economies of scale, economies of multiplant operation, economies of scope, and others).

[356] Generally, knowledge problems are indirectly treated under the more general heading of "synergies," or "economies of scope." Problems of knowledge hazards have been developed by studies mainly in the management area. *See, e.g.*, David Teece, *Economies of Scope and the Scope of the Enterprise*, *in* GILSON & BLACK, *supra* note 355, at 288 (discussing how intrafirm transfers of know-how ameliorate the hazards of opportunism because transactions become more idiosyncratic).

on why firms engage in mergers and acquisitions, joint ventures and licensing agreements. The knowledge taxonomy we advocate generates hypotheses about when vertical integration or market contracting will take place. For instance, it can explain which type of transaction will be chosen according to the knowledge type targeted. The limits result from the reality that not all knowledge can be propertized.[357] The ability or inability of the firm to bind a particular type of knowledge and avoid knowledge hazards, given the intellectual property regime available, thus shapes business transactions and contractual arrangements.

Strength of intellectual property protections is a crucial variable in determining whether companies will purchase knowledge inputs (primarily in the form of K_p) through licensing agreements or whether they will produce them, either jointly or through integrating the activity. Anand and Khanna have argued that licensing occurs in industries with strong intellectual property protections, but that joint ventures "should be more likely to occur in industries with weak IPRs [intellectual property right protections] to the extent that it is easier to monitor and control the activities of partners in such arrangements than via arms-length licensing contracts."[358] Arora and Merges argue that strong patent protections of a technological input make spin-offs more likely because the benefits from greater customization afforded by the independent research firm would outweigh rent dissipation by the spin-off.[359] According to this literature, markets for technology depend significantly on intellectual property protections. Thus, it is because technological innovation can be protected, even if imperfectly,[360] that markets for technology can develop and flourish.[361]

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[357] Tacit knowledge frequently cannot be rendered specific enough in order to be codified in the form of a patent. *See* Teece, *supra* note 95, at 189 (arguing that codified knowledge is easier to transmit and to imitate and that tacit knowledge is harder to transfer because of its difficult to articulate nature). Sidney Winter classifies knowledge continuums that have the following polar dimensions: tacit versus articulable, not teachable versus teachable, not articulated versus articulated, not observable in use versus observable in use, complex versus simple, and an element of a system versus independent. Winter, *supra* note 91, at 170. He argues that a position close to the left dimension of each continuum is indicative that the knowledge may be difficult to transfer, while a position close to the right dimension is indicative of easy transferability. *Id*.

[358] Bharat N. Anand & Tarun Khanna, *The Structure of Licensing Contracts*, 48 J. INDUS. ECON. 103, 128 (2000).

[359] Arora & Merges, *supra* note 211, at 470.

[360] *See* Teece, *supra* note 95, at 188. As has been note previously,

> [r]arely, if ever, do patents confer perfect appropriability although they do afford considerable protection on new chemical products and rather simple mechanical inventions. Many patents can be "invented around" at modest costs. They are especially ineffective at protecting process innovations. Often patents provide little protection because the legal requirements for upholding their validity or for proving their infringement are high.

Id.

[361] *See* ARORA ET AL., *supra* note 4, at 117 ("[O]ur analysis suggests that stronger IPRs can enhance the efficiency of technology transfers, and hence encourage the diffusion of technology, including parts of the technology that patents do not protect.").

Traditional corporate R&D strategy retained technologies in-house.[362] But markets for technologies offer technology-based firms the opportunity to "specialize in . . . development without having to invest in the . . . costly downstream assets" necessary for production.[363] As a result, the development of downstream markets for technologies permits the existence of smaller, specialized technology producers.[364] At the same time, greater specialization in the production of technological inputs upstream benefits downstream users of technology. With the increased development of markets for technology, integrating downstream or upstream therefore becomes less attractive. In this manner, markets for technology—and, by extension, legal mechanisms for appropriating innovations—"can imply a fundamental reconsideration of the appropriate boundaries of the firm."[365]

Holding all other variables constant, when knowledge is embedded in the product (K_p), and no tacit knowledge (in the form of K_i or K_o) is required to operate the product, the decision to acquire the asset becomes very attractive. If there are gains from specialization, the manufacturer will not vertically integrate, but each company will focus on producing a product it has a comparative advantage to produce. Therefore, manufacturers buy complementary assets necessary to their business by means of market transactions, so that they can avoid costly learning (K_i) or acquire the human and organizational resources (K_i, K_o) necessary to produce the input. The decomposable nature of K_p also accounts for the ability to outsource and license codified technologies.[366] Thus where production requires increased K_p inputs, a firm will tend to rely more heavily on market transactions to procure such inputs.

However, if the technology is such that the producer of the technology input and the manufacturer need to exchange a great deal of tacit knowledge in order to render the product functional at the plant, the buy decision becomes less attractive, and integration or other forms of joint production become more attractive. This occurs because tacit knowledge is more difficult to propertize, increasing the risk of exposure to knowledge hazards.[367] The ability to capture gains from investment in the production of tacit knowl-

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[362] *See* Rebitzer & Taylor, *supra* note 311, at 6–7.

[363] ARORA ET AL., *supra* note 4, at 224.

[364] *See* David C. MOWERY & NATHAN ROSENBERG, PATHS OF INNOVATION: TECHNOLOGICAL CHANGE IN 20TH-CENTURY AMERICA 41 (1998).

[365] ARORA ET AL., *supra* note 4, at 224; *see also* 1 ALAN S. GUTTERMAN, CORPORATE COUNSEL'S GUIDE TO TECHNOLOGY TRANSACTIONS § 5.007 (2005).

[366] To the extent that the production process can be broken down and compartmentalized into decomposable problems, outsourcing can occur. *See* Arora & Merges, *supra* note 211, at 454. In the chemical and pharmaceutical industries, outsourcing via licensing contracts has been increasing due to the availability of strong intellectual property regimes. *See* Bharat N. Anand & Tarun Khanna, *The Structure of Licensing Contracts*, 48 J. INDUS. ECON. 103, 126–28 (2000).

[367] Costs derive from the public nature of knowledge and include the possibility of leakage and problems of underutilization as described above. *See supra* notes 208–214 and accompanying text.

edge requires a variety of strategies.[368] Therefore, the relative quantity of tacit knowledge in a given business transaction affects the choice of the form of the transaction.

Mergers and other forms of joint production such as joint ventures or R&D partnerships are particularly appropriate to the development of innovations that rely on K_i. Mergers and joint ventures also allow the transfer of organizational knowledge (K_o), which cannot be easily blueprinted or packaged in licensing or market transactions.[369] These integrated or quasi-integrated structures diminish the risk and decrease the cost of knowledge hazards.

Looking only at the strength of intellectual property rights regimes does not tell us anything about the inputs required for production. Even when strong intellectual property rights exist for the manufactured products (K_p), if the knowledge required in the production process is mostly K_i or K_o, then joint production will occur anyway. The development of hybrid automobile designs provides an example. Toyota was the first to master the technology that is now embedded in a product (K_p), and it is propertized so that Toyota can sell the hybrid cars and retain ownership of the technology via its patents. GM and DaimlerChrysler have recently announced a hybrid engine joint venture. Even if the property rights are strong enough to assure that the product likely to be generated by the joint venture will be marketed, these companies decided to engage in a type of joint production or quasi-integration. The two companies did so because of the type of knowledge required in the production process, not the weakness of intellectual property type of rights in this industry, as evidenced by the strength of Toyota's patents. In this case, the nature of the knowledge input (and not the output) helps determine which type of transaction will take place.

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[368] Each firm chooses the strategy of knowledge management according to a wealth maximization perspective. *See* Winter, *supra* note 91, at 174. A firm may want to hinder involuntary transfers of knowledge, and therefore try to keep its knowledge sets non-codified as much as possible to avoid imitation by competitors. *Id*. On the other hand, a firm may want to share its technological and organizational capabilities in order to benefit from licensing agreements, joint ventures, or mergers. In this case, it may pursue a strategy in order to articulate it knowledge and make it teachable. *Id*. at 174–75; *see also* Harbir Singh & Maurizio Zollo, *The Impact of Knowledge Codification, Experience Trajectories and Integration Strategies on the Performance of Corporate Acquisitions* 27–29 (U. Pa. Wharton Fin. Inst. Ctr., Working Paper No. 98-24, 1998). The authors analyze knowledge management strategy in acquisitions. They measure codification by the number of post-acquisition processes developed in the organization to address several areas such as financial evaluation, due diligence, information systems, human resources, and sales-product integration. *Id*. at 27. Their results suggest that the high codification of post-acquisition processes have a positive effect on the performance of highly complex post-acquisition processes. *Id*. at 29. On the other hand, high codification of post-acquisition processes can harm performance in the context of simple processes, because it can lead to excessive bureaucratic load. *Id*. These findings suggest that there is an optimum level of codification of knowledge necessary to make knowledge transfer effective. *Id*. at 31.

[369] Bruce Kogut, *Joint Ventures: Theoretical and Empirical Perspectives*, 9 STRATEGIC MGMT. J. 319, 323 (1988).

Thus, the stage of the technological cycle may impact the business form. Knowledge generation that relies mostly on K_i is more suitable to joint-production arrangements as opposed to market arrangements. This occurs for two reasons. First, knowledge transfer contracts cause special moral hazards. Leakage of knowledge resources can occur both on the side of the producer and on the side of the manufacturer. Hoarding or failure to share knowledge may be enhanced in market transactions. Second, transfer of tacit knowledge is costly because it involves difficult knowledge exchange between employees of the manufacturer and the producer of the technological input. If a firm must spend a great deal of time learning about how to use a knowledge input, then producing the input in house is more attractive.[370] The analysis of knowledge inputs, therefore, strongly influences the form of business transactions. While a thorough development of these relationships goes beyond the scope of this paper, we note the promising avenues for further inquiry.

CONCLUSION

This Article provides a new approach to corporate organizational structures by focusing on knowledge inputs, an important variable largely neglected by legal scholars. This approach analyzes the types of knowledge resources that firms employ in their production processes and how legal institutions impact firm organizational structure by binding these knowledge types to the firm. Law has greatly influenced knowledge management. The development of intellectual property protections and contract law have deeply affected the strategies employed by firms, as well as firm organizational structure itself. This Article shows that each knowledge type—and the legal mechanisms used to protect it—influence firm organizational structure.

Firms will try to maximize the use of knowledge resources in order to maximize profits, while also diminishing the occurrence of knowledge hazards such as leakage and hoarding. To do so, firms create particular organizational arrangements such as steeper or flatter hierarchies, adopt particular compensation systems, and engage in certain types of business transactions. This Article analyzes these organizational strategies as evidenced by mass production, high-tech, and law firms, as well as in business transactions.

Based on our theory, we can explain why firms develop centralized or flatter hierarchies. Hierarchies effectuate knowledge-substitution and allow firms to economize costly knowledge embedded in individuals. The adop-

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[370] ARORA ET AL., *supra* note 4, at 115. As one group of scholars has pointed out:

> [T]here is a greater cognitive distance between organizations, which raises the cost of transferring tacit and context dependent information. Different units within an organization are more likely to evolve a common shared understanding and a common code for communicating the knowledge than different units in separate organizations. The shared context lowers the relative cost of transferring tacit knowledge inside an organization.

Id.

tion of steeper organizational hierarchies in mass production firms and of flatter hierarchies in high-tech and law firms demonstrate how different organizational structures result from the pursuit of an efficient knowledge allocation.

In our analysis of the development of American manufacturing firms, we argued that the change from the C-form structure to the M-form structure was largely driven by changes in corporate knowledge requirements, mainly from the K_p to the K_i form. For diversification to be possible, firms had to engage in new product and research development, requiring the use of individual knowledge not only at the top, executive-levels of the organizational hierarchy. Increasing levels of K_i at several levels of firm hierarchy required decision-making rights to be collocated with relevant knowledge, so as to maximize the use of knowledge resources in the new M-form corporation.

In high-tech companies, the need to retain employees and to deal with knowledge hazards, such as leakage and hoarding, has led companies to adopt broad stock options plans as part of their compensation packages. We show the shortcomings of the standard agency cost view, according to which stock options are used to incentivize top management. This *managerial power view* posits that stock options serve the self-interest of top executives. In contrast, the *perceived-cost view* posits that accounting benefits have driven the use of stock options. Based on a knowledge resources perspective, we adopted a *retention view*, concluding that stock options are assigned to other employees as a means of stimulating them to stick with the firm and share their knowledge. Our analysis provides a normative conclusion that counsels against the current one-size-fits all approach in the debate over the use of stock options.

Knowledge considerations also have a strong explanatory power concerning the organization of law firms. These firms are organized so as to achieve increasing gains from knowledge specialization. The hierarchy among partners and associates is designed to efficiently allocate decision and residual rights to those considered more knowledgeable. Client relationships are usually conducted by those who already share the residuals in order to avoid leakage from associates. The sharing model of splitting profits also promotes an efficient distribution of cases or transactions among those most capable of handling them. Recent changes in the organizational structure of law firms, such as the increasing number of staff and contract attorneys and the consequent increase of hierarchy levels, are also explained by changes in the type of knowledge used in these organizations.

In the case of business transactions, we suggested that deals that rely on different types of knowledge will assume different legal forms. Market transactions will occur when knowledge is mostly embedded in products, and arrangements of joint-production will tend to occur when individual knowledge is more important for a given transaction.

This Article initiates a new debate concerning the relation between law and knowledge resources for firm organization. We have put forward several hypotheses that require empirical investigation and theoretical modeling. At the same time, we hope to contribute to the development of the knowledge-based theory of the firm in the economics literature. Organizational economics has already recognized the importance of legal rules to the knowledge structure of firms in the case of patents. The impact of law on knowledge management, however, is much more extensive and will hopefully continue to be of increasing interest to economists.

The typology we have developed for distinguishing different types of knowledge in the production process provides an important new perspective on the development of different types of firms. It enables us to reframe some of the standard positive explanations for firm organizational arrangements and firm compensation policies. Our approach suggests that the influence of knowledge deserves further special attention, especially as to how knowledge requirements influence firm ownership structures.

The principle of efficient knowledge allocation is also an interesting guide for normative proposals. Policymakers should analyze the influence that intellectual property rights and related contractual arrangements exert over internal knowledge management. They should also consider and promote efficient knowledge allocation through corporate reforms. Crucial to successful coordination and decision-making is the collocation of relevant knowledge with the decision-making rights and authority at the various levels of hierarchy within the business organization. This can provide new perspectives for current corporate reform analysis. An interesting avenue would be to discuss, for example, whether the recent governance changes of Sarbanes-Oxley promoted this rationale. We leave this endeavor for future publications.