Property as a Complex Adaptive System: 
How Entrepreneurship Transforms Intellectual Property Structures

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Abstract:

This paper examines the evolution of property rights from a systems-based capital-theoretic perspective. The approach emphasizes how entrepreneurs create capital combinations by connecting capital goods—defined widely to include property rights, such as patents—in their production plans (Lachmann 1956, Harper and Endres 2010). We apply this theoretical perspective to explain the formation, integration and transformation of property rights structures. The approach treats the property rights structure as a complex adaptive system and studies its modular multi-level architecture. The property rights system is a web-like network that exhibits increasing structural complexity and newly emergent properties as it evolves. We focus upon how entrepreneurs are major causal agents in reconfiguring intellectual property structures and how their actions change complementarity relations between property rights that are used in production. Entrepreneurs discover gaps in the property rights system—discrepancies between how rights are currently structured and how they could be structured to facilitate production of the kinds and qualities of goods and services that consumers demand most urgently. As they organize production to exploit profit opportunities, market-based entrepreneurs repartition and reshuffle existing intellectual property rights (IPR) into new modules, thereby changing the modular decomposition of the property rights system. Such remodularization of property rights is tantamount to capital regrouping and has implications for economic organization. We examine how entrepreneurs create novel forms of economic organization—such as patent pools—that encapsulate more complex combinations of the basic building blocks of intellectual property.

We apply our framework to investigate the MPEG-2 patent pool for digital data compression technology. This pooling arrangement materially affects the boundaries to intellectual property and remodularizes de facto entitlements to knowledge assets. It constitutes an interpolation of a new meso-level of economic organization within the macro IPR structure.
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There is a legal system, and it is complex and adaptive. We can leave it at that and intuit propositions that seem likely to follow, or we can dive headfirst into law’s complexity to swim amidst its chaos, its feedback networks, its self-organization, its scales, its emergence, and its sheer dynamism.

(Ruhl 2008: 888)

1. Introduction: The legal order as a capital structure

This paper views the law in general and the system of property in particular as constituting a complex capital structure. Following Fisher (1906), we define capital broadly to include any resource—whether natural, artifactual or human—that produces a flow of services that people value (see too Tobin 2005). “The importance of capital goods lies not in their physical qualities but in the service streams to which they give rise” (Lachmann 1956: 86). The upshot is that any resource qualifies as capital if it is used in a production plan. Consequently, law qualifies as capital provided that people apply it in production and view it as capable of rendering services over time that they desire. Legal rules, such as property rights, are, directly or indirectly, instruments of production. They are like blocks of Lego that can be mixed and matched in endless combinations. They function as higher-order capital goods that help produce lower-order goods (e.g. consumer goods). They derive their economic significance and their property of being capital from their use within the production plans of entrepreneurs, firms and households. Property rules are an integral part of the knowledge structure that mobilizes and guides the transformation (manufacture, transportation and storage) of materials, energy and information in the economic system (Boulding 1978, Metcalfe 2010).
The system of property is a structure in the sense that its heterogeneous elements are connected and interact. It is not a mere aggregate or stock. There is some patterning in the diverse array of property rights. These rules cannot be combined arbitrarily; they have to fit together and mesh with other types of inputs (cf. Lachmann 1956: 4). By itself, a single property rule or property right cannot render any services; it can only obtain the status of being capital through being combined with other capital goods, including other legal rules. In addition, the property rights system exhibits a great deal of structural patterning at more than one level. It emerges as a nested multi-level structure—a system of systems in which interrelated subsystems in turn consist of lower-level subsystems and connections between them.

According to this capital-theoretic conception, the property rights system has a prominent place in the realm of production, not just exchange. Property rules participate in the production process. Property law is not a “freestanding governance structure” that hovers over people and transactions (cf. Langlois 1995: 251); it is a structure of rules and connections “installed” in a social network of economic actors and is deeply embedded in the DNA of doing business and carrying out productive tasks. The law of property and contract are part of the core connective structure of rules that supports production and exchange in the economic system. It provides significant connections—“invisible bridges”—between entrepreneurs, consumers and resource owners (Hadfield 2011: 6). There is no such thing as an abstract legal system that exists separately and apart from productive human participants. “Law exists in order to be applied” (Carleton Kemp Allen 1927: 172, 441). Its only existence is in its applications.

Recognizing that the legal order of property is a capital structure serves to sharpen our understanding that property is also a complex adaptive system. The property rights system is:
1. Complex: it contains many heterogeneous elements that are interconnected. The law possesses a higher order of complexity than systems involving mere application of given or acquired knowledge in that it involves interactive knowledge structures and mental models (in Foster’s (2005) typology, the legal order is “fourth-order complex”).

2. Adaptive: There can be change in the structure of property rights in the sense that there is some plasticity in the connections among its elements.

3. Modular: it comprises functionally differentiated subsystems (relatively stable subassemblies) that are connected to one another.

4. Stratified: each module of property rights is both a system and an element of a higher-level system—that is, the structure of property rights contains multiple levels of order and interaction.

5. Knowledge-generating: the knowledge generated by the property system includes classifications meaningful to the participants in the context of the legal order (McQuade and Butos 2009, Tulloh and Miller 2006: 93). These classifications exist at multiple levels and adjust continuously to changing circumstances. As a kind of capital formation process, the ongoing creation of the property rights structure is a social learning process that is self-organizing and selective.

Ruhl (2008) identifies an extensive catalog of characteristics of the law that make it a complex adaptive system. These agent-based and systemic features apply with equal force to the law of property in particular. For instance, agents in the property system are heterogeneous, consisting of several different classes (e.g. courts, legislatures, lawyers, clients); they follow local rules of interaction; and their interactions can give rise to sharp discontinuities, such as when courts overrule established precedent unexpectedly or old statutes (e.g. the Patent Act 1952) are
amended significantly. The property system generates emergent features, such as the capacity to coordinate people’s expectations, that cannot be reduced to the behavior of individual agents or individual property rules taken in isolation; the system exhibits path-dependence, such as when judicial interpretations build on prior cases; and the common law of property organizes itself around a set of core doctrinal rules, such as the rule of first possession, that lend stability to the system over time.

In addition, previous empirical studies have found that American common law exhibits a scale-free network structure that is dominated by a few “hub” cases (nodes) that receive the vast majority of citations (links). Out of approximately four million federal and state cases, a mere one thousand cases receive around 80 percent of the total number of citations (T. Smith 2007: 313, 346). Rather than a seamless web, the law is “uneven, clumpy” and gappy, with dense clusters of legal decisions and many missing connections (T. Smith 2007: 315). Similarly, an empirical study of the patent citations network in the U.S. found that it exhibits the “small world property”—only a small number of steps between nodes is needed to connect any two nodes in the network (Strandburg et al. 2006). The presence of the small world property means that it is possible that a small number of highly connected hub patents are integral to many separate technological fields (p. 1346). In addition, the social structure of the American federal judiciary is dominated by a small number of socially prominent judges (Katz and Stafford 2010).

Treating a system of property rules as a kind of capital is not without precedent in the law and economics literature. For instance, Hayek describes abstract rules of legal order as a “kind of instrument of production” that assist people in making their individual plans so that they are better coordinated with the actions of others (Hayek [1944] 2007: 113). Such legal rules are instrumental in the sense that they are useful for as yet unknown ends of as yet unknown people,
rather than useful for particular ends of particular people (p. 114).¹ In a seminal article, Landes and Posner (1976) view the body of legal precedents as constituting a “stock of legal capital subject to depreciation” (p.262) that generates a flow of information services that can be quantified in monetary terms. Their conception of capital is cast in a neoclassical production function and is consequently very “jelly-like”: legal capital is an aggregate, measured by a scalar magnitude, that is smoothly synchronized to equilibrium requirements. More recently, Hadfield’s (2011) concept of “legal infrastructure” comports well with the notion that property law is a capital structure. Legal infrastructure is a form of “socially available capital that produces a stream of services” (p.29). Legal infrastructure is the “accumulated stock” of legal resources, comprising legal rules and other materials, that is produced by “legal actors”—broadly defined to include judges, legislators, regulators, arbitrators, lawyers, and other legal practitioners. Legal rules are intermediate goods produced as output by the legal sector that are available for use as inputs in other sectors (p. 30). They are “essentially economic inputs” (p.9) to “an economic output” (p. 29). Similarly, according to Mackaay (1999, 2002), legal property rights, such as copyright, can serve as “fences” that are used to obtain exclusive control over scarce resources. These fences behave like “other economic goods” (Mackaay 1999: 252). Fencing techniques are themselves scarce goods like the objects they fence in (Mackaay 2002: 136).

By developing the perspective that property systems are capital structures, this paper addresses two related lacunae in the economic analysis of law and the economic theory of capital. First, it addresses the lack of emphasis in the economic analysis of law on production and entrepreneurship as a capital-creating force in the economic system. The predominant contractual

¹ For related approaches, see too Lachmann (1971), Foss and Garzarelli (2007), Vaughn (1999). Similarly, Barnett (2011: 856) conceives of intellectual property rights as “an instrument for organizing intellectual production”. He argues that strong patents provide firms in technology markets with a means to vertically disintegrate their supply chains through contract-based relationships, which in turn induces the formation of secondary trading markets in intangible technology inputs (i.e. new ideas).
view of economic organization in this literature overemphasizes the exchange aspects of the firm (i.e. buying and selling of inputs and outputs) and the design of governance structures to mitigate unproductive rent-seeking (Coase 1988; Langlois and Foss 1999). To rectify this gap, this paper grounds analysis of the evolution of property rights in a systems-based theory of capital that squarely locates the function of entrepreneurs in making and revising capital combinations in a world of unexpected change (Lachmann 1956: 13, 16, 54, 98-99). Production is brought center state, not quarantined off. Second, the paper addresses the lack of attention given to property rights in the theory of capital. The theory of capital tends to treat the basic structure of property rights as a datum, as exogenously determined. It does not focus upon how property rules can affect the structure of production plans in the economic system as a whole. The theory of capital does not examine how the structure of legal entitlements affects who (i.e. which entrepreneur) gets to select the uses of capital goods and their decisions to transform, combine, regroup or scrap capital goods. It does not investigate the question of what effects changes in legal claims to productive resources have on different levels of the capital structure and the economic system.

1.2 Objectives and organization of the paper

The objective of this paper is to explain the formation, integration and transformation of property rights systems at multiple levels of complexity. We are interested in questions relating to the emergence, boundaries and internal structure of systems of property rights. We study the overall topology of the property rights system—the general connecting principles underlying the structure of system—rather than the efficiency properties of individual property rules. The property rights system is a web-like network of rules that exhibits increasing structural

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2 The focus on “commercialization” in recent legal research on intellectual property rights is consistent with our emphasis upon production relations. See, for example, Barnett (2011) and Kieff (2001, 2005).
complexity as it evolves. The network consists of nodes and channels through which information, materials and energy flow.

This scope of this paper is limited to a positive analysis of property rights and how entrepreneurs create new structures of property rights in their capital formation activities. It is not concerned with normative questions, such as the desirability or otherwise of having a patent system or the legitimacy of patents. It takes the patent system and other statutory forms of intellectual property protection as given. Patents and copyrights are treated as species of intellectual property that are available for entrepreneurs. They adapt to the world as they find it.

The organization of the paper is as follows. In section 2, we outline the systems-based theory of capital and its implications for entrepreneurship and economic organization (Endres and Harper 2012; Harper and Endres 2010, 2011). We focus upon those aspects most relevant for explaining the evolution of intellectual property rights. Entrepreneurs discover gaps in the property rights system—discrepancies between how rights are currently structured and how they could be structured to facilitate production of the kinds and qualities of goods and services that consumers demand most urgently. As they organize production and orchestrate assets to exploit profit opportunities, market-based entrepreneurs repartition and reshuffle existing property rights into novel modules. Section 3 applies this theory to investigate the emergence and structure of patent pools. We examine how entrepreneurs use private-ordering rules to form patent pools that encapsulate basic building blocks of intellectual property. Patent pools are explained as emergent capital combinations that interpolate a new level of order into the property rights system. In section 4 we apply our framework to investigate the architecture, interface rules and formation process of one real-world patent pool: the MPEG-2 patent pool which combines patents in digital data compression technology used in digital television and DVDs.
2. Entrepreneurship as the causal agent in the evolution of intellectual property rights structures

2.1 Gaps and obstacles in the structure of property rights

This paper takes the notion of a network as the basis for its perspective on the nature of the legal order. The network comprises legal rules and connections between them. The legal order has a spatial, temporal and social structure. The network is incomplete—it contains gaps, because elements and connections are missing. For example, legal gaps can arise from the absence of property rights so that a resource is unowned, as in the classic tragedy of the commons. The law is an imperfect network rife with holes, obstacles and ill-defined pathways and nodes: “There are holes and tears in the net, obstructions (knots) along the pathways, and some nodes and pathways, where they exist, are poorly defined and poorly marked or entirely unmarked from the viewpoint of elements of other nodes” (Leibenstein 1968: 77). Thus, the legal property rights structure is not a fully connected system located in “integral space” in which every element (e.g. agent, rule) directly affects every other element in the system. Rather, there exist clusters of local interactions: each agent interacts with only some other agents; each legal rule interacts with only some other rules (Potts 2000: 19, 25-26). Local interactions between rules generate a modular

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3 In contrast, Lachmann (1971) starts his analysis of legal order at the opposite end of the “geometry of legal space” to what we presume. He claims that “the legal system is a seamless web. It has no ’gaps’” (Lachmann 1971: 76). (The idea that the law is a seamless web is often attributed to the English legal historian F. W. Maitland (1898), though he never quite said it directly.) Lachmann’s invocation of the seamless web metaphor is an attribution of geometric structure to the interactions between legal rules. What does he mean when he says that the law has no gaps? The idea is open to several interpretations. As used by Lachmann, the seamless web metaphor requires logical consistency (i.e. the absence of contradictions) between all legal rules, such as rules of property and contract. Logical consistency is a condition for the coherence of the legal order. No two legal institutions can be inconsistent because almost all legal rules are implicated directly or indirectly in every market transaction (p.70, 76). If legal rule $i$ features in the market plan of individual $A$, the coherence of the legal order requires that this rule mesh perfectly with another legal rule $j$ upon which individual $B$ bases his market plan, even though the two legal rules $i$ and $j$ may never appear together in the very same market plan and $A$ and $B$ may never engage in direct exchange with each other. According to Lachmann, if rules $i$ and $j$ gave the two market participants conflicting signals about who owns
architecture in which legal rules and other legal inputs can be categorized into discrete areas even though boundaries may not always be that sharply delineated. For example, intellectual property law consists of separate legal subsystems for patents, copyrights, trademarks, and trade secrets. “The landscape of intellectual property comprises a highly variegated array of quite distinct legal regimes” (Menell and Scothmer 2007: 1475). New connections do not just happen instantaneously or automatically. Interactions and flows of information, materials and energy among elements take place in real historical time.

Logical connections between legal rules are important but not primary in this analysis. Moreover, logical coherence of the legal order is neither necessary nor sufficient for “praxeological coherence”—that is, coordination in the order of market actions that take legal rules as reference points (Rizzo 1999: 500). The system of property rights is constituted by sets of mutually sustaining expectations on the part of individuals in the economy (Kirzner 2000: 83). Praxeological coherence means that agents have consistent expectations about their (future) control over particular resources; they have mutually dovetailing expectations about who owns what and who has the right to do what.

There are always gaps in the system of property rights within which economic production and market exchanges occur. The property rights framework is never perfectly delineated in advance. They are always incomplete. Full specification of the rights to an asset would require that both the existing and potential owners of an asset have complete knowledge of all its valued attributes (Barzel 1997: 4; Harper 2011: 5). The potential infinity of rights makes present knowledge, on the part of both agents and the observing economist, of all possible future rights impossible. ‘If
there is such a thing as growing human knowledge, then we cannot anticipate today what we shall know tomorrow’ (Popper 1963: vi). The emergence of new property rights to newly discovered attributes of assets is unpredictable in principle. Property rights are always incompletely defined because of irremediable imperfections of our knowledge and the prohibitive costs of fully specifying legal rules and regulations. In the case of individual patents, the incompleteness of property rights means that there is a gap between the de jure reach of the patent system (i.e. legal rights) and the practical exclusionary effect of patent law (i.e. de facto, economic rights). The incompleteness of patents and the high monitoring and enforcement costs of the patent system provide shelter for infringing behavior (Eisenberg 2011). Because of the Hayekian knowledge problem, judges and legislators cannot make rules that anticipate all future legal and economic developments (including the growth of our knowledge). For example, at the time when the traditional conception of property in land (which held that ownership of the ground extended from the center of the earth to the heavens) became firmly established in English common law in the late sixteenth century, no one could have foreseen the recent emergence of new technologies for use of the deep subsurface—such as heat mining and carbon sequestration (Sprankling 2008).

One of the potential obstacles or “knots” in the legal order that can impede the diffusion of patented technology is the alleged “patent thicket”. Patent thickets are dense networks of overlapping and blocking intellectual property rights owned by different firms (Shapiro 2000). For example, Heller and Eisenberg (1998: 698-9) suggested that a proliferation of patents covering individual gene fragments would result in underusage of research materials and inhibit
biomedical research. In the absence of patent pools, patent thickets require firms seeking to commercialize new technologies to negotiate individual patent licenses with multiple patent holders. Patent thickets can mean that there will be many conflicting claims of intellectual property ownership among many patent owners (Bednarek and Ineichen 2004: 2). Patent thickets are the result of human action but not of human design, and hence qualify as a “dysfunctional” form of spontaneous order, in that economists do not usually consider them to be benign.

A patent thicket is an instance of an “anticommons” problem where the existence of multiple rights to exclude leads to “inefficient” underutilization of resources (“inefficient” relative to a zero transaction-cost benchmark) (Heller 1998). There is an anticommons problem in which no firm has an effective right to use the intellectual property but many firms have the right to veto a proposed use, resulting in an underusage of the patented invention. The patent thicket emerges because multiple firms are assigned rights of exclusion, and the exercise of these patents creates interdependencies that are not included in agents’ decision-making. The patent holders impose external diseconomies on others who also hold exclusion rights (Buchanan and Yoon 2005: 3-4). The overwhelming rights of exclusion held by other patent holders effectively constrain and potentially eliminate each patent holder’s right of use (Parisi et al. 2005: 584). The patent holders are not able to coordinate their actions, so that the actions of each blocks the actions of others. According to the anticommons thesis, the magnitude of the opportunity loss (in terms of nonrealized profits) increases with the number of firms assigned simultaneous exclusion rights related to the patented technology.

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4 Epstein (2010) considers that anticommons problems are overstated. “Typically, no IP owner wants to keep a wasting asset on the shelf. In those cases where a patent is not exploited, the typical explanation is that the patentee holds substitute patents of greater commercial promise” (p. 470). See too Kieff (2007: 107).
It seems that the patent thicket arises because intellectual property rights have been cut too thin—that is, partitioned into too many small fragments. The patent system has been “inefficiently modularized” from the perspective of entrepreneurs and end-users (Langlois 2002: 29). Unlike cases of unified ownership, commons and anticommons situations entail rights of use and rights of exclusion that have “non-conforming boundaries” in that these rights are not exercised over a similar domain (Parisi et al. 2005: 584). If rights are cut too thin, the presence of prohibitive and asymmetric transaction costs will make it difficult to assemble rights into larger, more appropriately sized bundles (Heller 1998; Heller and Eisenberg 1998; Parisi et al. 2005). Consequently, the market will not elicit cooperation among entrepreneurs where the transaction costs of overcoming patent thickets are prohibitive (cf. Kirzner 2000: 83).

2.2 Entrepreneurial regrouping of capital combinations that embody intellectual property

The existence of holes and obstacles in the property rights structure provide opportunities for entrepreneurship. Entrepreneurship is the “self-organizing impetus” that fills gaps, develops connections and generates ordered complexity in the property rights structure (Foster 2000: 319). Entrepreneurs are alert to profitable opportunities for voluntary market exchanges that are implicit in the status quo pattern of property rights. Whereas political entrepreneurs (“rent seekers”) use the coercive powers of the state to re-allocate property rights through uncompensated transfers, market-based entrepreneurs pursue profit by trading property rights in resources through non-coercive means (Ricketts 1987: 462). Entrepreneurs who establish private rights or a common property regime in newly discovered, hitherto unowned and unused

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This paper focuses upon market entrepreneurship rather than legal or political entrepreneurship. An example of the latter is copyright owners’ lobbying Congress to implement legislation (the Digital Millennium Copyright Act of 1998) that increases penalties for copyright infringement on the internet and criminalizes the circumvention of technological protection measures to control access to copyrighted works. See Litman (2001: 122-149). A more recent example is the America Invents Act (2011), the most significant change to the U.S. patent system since 1952, which “will protect large, entrenched companies at the expense of market challenging competitors” (Kieff 2011: 2).
(or abandoned) resources are not challenging the property rights of others and no unwilling transfers are involved, so their actions qualify as market-based.

Entrepreneurs discover gaps in the capital structure—here broadly construed to include the structure of property rights. They discover holes and obstacles that could conceivably be surmounted at a profit. For example, a “new breed of entrepreneurs” is “patent trolls” (Chan and Fawcett 2005-6: 1). These patent dealers act as intermediaries and do not employ the patents they acquire in production. They discover gaps between de jure and de facto patent rights which represent profit opportunities. Unlicensed use of patented technology is extensive in commercial production because it is very costly both for technology developers to assert patents (e.g. because of high litigation costs) and for technology users to identify the patents they might be infringing.6 The increasing number of weakly enforced rights in the patent system lures entrepreneurs who can profit by buying up these rights and then developing creative strategies for asserting them. “Patents that are worth little to their initial owners may be worth more to entrepreneurs who enjoy a cost advantage in asserting patents against users or who own complementary assets (such as large patent portfolios) that either increase the value of the patents or lower the costs of asserting them” (Eisenberg 2011: 68). These patent entrepreneurs reduce the gap between the expansive legal rights of the patent system and the narrower economic rights experienced in practice. Their actions improve market coordination relative to the status quo benchmark of legal rights (i.e. current patent law).

6 Willful patent infringers who rely upon high detection and enforcement costs to shelter themselves from patent assertion are capturing value through uncompensated transfer and challenging the rights of the patent owner from the perspective of the legal status quo. But the status quo is not an objective fact. The boundaries of patents are not perfectly specified in advance. “It is difficult—and in many cases impossible—to know whether one is ‘trespassing’ upon another’s intellectual property right... [P]atent claims lack the certainty of real property deeds... Not until the Federal circuit rules on the meaning of any claim can the patent owner or its competitor know what is owned and
However, the entrepreneurial function *vis-á-vis* capital creation is not limited to arbitrage or buying and selling property. As they perceive incoherence or holes in the capital order, entrepreneurs also reorganize production. They bring together heterogeneous capital goods (defined broadly to include patents and other intellectual property rights) into new combinations, and reshuffle and dissolve existing combinations (Lachmann 1956). Capital goods used in the same production plan stand in relations of complementarity to one another. Complementarity thus derives from the particular production plan being implemented by the entrepreneur; that plan is itself derived from the entrepreneur’s expectations about the future constellation of demand and supply (Horwitz 1994: 286). Entrepreneurs experiment to find better capital combinations (including better combinations of intellectual property rights) that meet the demands of the market. As they revise their production plans, entrepreneurs substitute some capital goods for others. Substitutability is a phenomenon of unexpected change and an integral part of the process of capital regrouping. Whereas “complementarity is an aspect of any given plan, substitutability is an aspect of contemplated changes in plans” (Lewin 1994: 242). Complementarity thus relates to the coherence of the capital structure, while substitutability relates to its adaptability. These relationships are not mutually exclusive alternatives. Taken together, these relationships bring order to the capital structure and help maintain order in the face of unexpected change. The construction of new capital combinations gives rise to more complex layers of capital complementarities (Lachmann 1956: 80, 84). As the range and variety of capital goods (especially of an indivisible character) increase, the capital structure exhibits a higher degree of complexity.

what isn’t” (Lemley 2005: 1100). The legal doctrine of equivalents and other context-dependent rules also increase uncertainty over the scope and boundaries of patents (Eisenberg 2011: 55).
2.3 Specifying capital combinations that embody intellectual property

As they create capital combinations, entrepreneurs make decisions on the particular form of rule complexes for their enterprises. This process is referred to as specification. Entrepreneurs specify the architecture, interfaces and standards that pertain to these rule complexes. As they knit capital goods together into new combinations, entrepreneurs select, order and configure legal rules in particular ways to generate a specific rule structure. For example, the entrepreneur specifies the form of legal entity for organizing the venture. At the most general level, entrepreneurs make use of abstract legal rules of property and contract and apply them to specific settings in light of their own particular knowledge and purposes. These rules exist in order to be applied and have a very wide range of potential applications. Entrepreneurs need not be aware that they are following or using these legal rules. In the process of specifying rule complexes, entrepreneurs turn abstract formal rules into productive rules-in-use in actual economic contexts. They thereby plug abstract rules into operational routines and processes of production and exchange. Because abstract rules of property and contract by themselves are not sufficient to direct and coordinate productive activities of the firm, entrepreneurs combine these rule sets with more concrete rules of organization and specific commands (cf. Hayek 1973: 48-52). Rules of organization fill in the gaps left by abstract rules and commands. Entrepreneurs’ specifying activities are forward-looking and “forward-matching” in that entrepreneurs combine rules today in the expectation that the output generated by those rule combinations will be demanded by end-users in the future and sold at a profit (Endres and Harper 2012).
Table 1: Legal and non-legal mechanisms for protecting different types of knowledge

<table>
<thead>
<tr>
<th>Legal rules and private contracts that propertize knowledge assets</th>
<th>Type of knowledge module or capital asset</th>
<th>Non-legal rules and devices to protect knowledge assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical capital (i.e. knowledge embodied in machines and products)</td>
<td>Physical fences</td>
<td>Technological protection measures (e.g. encryption, watermarking, &quot;potting&quot;, hybrid approach to breeding new plant varieties)</td>
</tr>
<tr>
<td>Patents</td>
<td>Secrecy measures (e.g. keeping idea to oneself and not sharing it)</td>
<td>Threat of withholding service by professional possessing highly individualized information (Mackaay 1990: 893)</td>
</tr>
<tr>
<td>Trade secrets</td>
<td>Trade secrets</td>
<td>Restricting access to IP to a handful of insiders</td>
</tr>
<tr>
<td>Employment contracts and pre-invention assigning agreements</td>
<td>Confidentiality agreements</td>
<td>Business and marketing strategies, investment in complementary assets</td>
</tr>
<tr>
<td>Confidentiality agreements</td>
<td>Confidentiality agreements (for employees and customers)</td>
<td>Trust and goodwill</td>
</tr>
<tr>
<td>Patents</td>
<td>Covenants not to compete in labor contracts</td>
<td>Office and laboratory security measures</td>
</tr>
<tr>
<td>Trade secrets</td>
<td>Trade secrets</td>
<td>Norms against theft</td>
</tr>
<tr>
<td>Employment contracts and pre-invention assigning agreements</td>
<td>Confidentiality agreements</td>
<td>Norm-based IP systems</td>
</tr>
<tr>
<td>Patents</td>
<td>Covenants not to compete in labor contracts</td>
<td>Norms of life-time employment (e.g. in Japan)</td>
</tr>
</tbody>
</table>

Source: First four rows adapted from Gorga and Halberstam (2007: 1143, 1148, 1149, 1162)

In the context of intellectual property, entrepreneurs make decisions about the specific legal and other rules they will use in order to control their knowledge assets and capture the profits generated by their innovations. As a first approximation, we can assume that they select legal rules of property from a fixed menu of intellectual property forms: patents, copyrights, trade secrets and trademarks (Merrill and Smith 2000: 19-20). These property forms grant exclusive
rights on new creations of intellectual capital, such as specific inventions, particularized expressions and source-identifying marks (Lee 2008). The menu of property forms qualifies as a structure in Lachmann’s sense of the term because it is sufficiently stable to exhibit “the firm outline of a clear and distinguishable pattern” (1956: 57). The relative stability of the menu of property forms is a result of the *numerus clausus* principle, which limits intellectual and other property rights to a small closed class of well-defined types. (*Numerus clausus* means “the number is closed”.) The principle discourages judges from recognizing new or customized forms of property rights. The principle is explicit in civil law systems and implicit in common-law systems (Merrill and Smith 2000, 2001). From the perspective of individual entrepreneurs, the menu of legal property forms is thus a “relatively absolute absolute” (Buchanan 1999) that imposes constraints on their decision-making and capital-creating activities; the menu itself is not a choice variable. However, the menu of intellectual property forms is not just a constraint on entrepreneurial action. By making available standardized building blocks akin to standardized Lego pieces, it also defines pathways for doing things—it provides routines for “propertizing” knowledge assets. In short, the law of intellectual property comprises rules-as-routines as well as rules-as-constraints. “Structures both enable and constrain; indeed, they enable because they constrain” (Loasby 1999: 124).

The process of deciding IP protection for knowledge assets is really an act of specifying the uses of these higher-order capital goods (IP property forms). The specification will depend, among other things, on the nature of the module (type of capital asset) that encapsulates the new knowledge and the characteristics of the new knowledge (e.g. whether it is a product or process innovation, the degree to which it is tacit or codified). See Table 1. Patents afford considerable protection on new chemical products, for instance, but are generally ineffective at protecting
process innovations in most manufacturing industries (Teece 1986; Grindley and Teece 1997). Trade secrets are particularly important for some process innovations (e.g. industrial-commercial processes for cosmetics) (Levin et al. 1987).

The generation of novel capital combinations requires the complex integration of different types of knowledge. Each capital good in the combination embodies different knowledge about novel production processes and how to execute them (Baetjer 2000). For instance, Google estimates that the smartphone might be open to a quarter of a million patent claims (Lohr 2011). Accordingly, entrepreneurs mix and match different intellectual property rules to protect different aspects of a complex innovation that comprises multiple components. The entrepreneur makes a choice to patent some parts, while deciding to keep other parts as a trade secret (Denicolò and Franzoni 2006: 21). In the software industry, for example, entrepreneurs use trade secrecy to protect source code and use patents to cover functional features of computer software (CHECK: algorithms??; programs in object code form?) (Menell and Scrotchmer 2007: 1498, 1507; Ottoz and Cugno 2011: 220). Hence, these two intellectual property rules can stand in a relation of complementarity in the context of the same production plan. Moreover, this complementarity relation can be combined with a temporal relation: e.g. trade secret \( x \) is complementary to patent \( y \) in the production plan \( z \), and the use of \( x \) is planned to precede the use of \( y \) (Harper and Endres 2010: 38). For instance, trade secrecy protection can be used during earlier stages of the innovation process in which the patent is pending (Erkal 2004). Trade

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7 If entrepreneurs consider an innovation is not worth patenting, they may also choose to publish it so as to preempt patenting by competitors who might later block their use of the innovation (Grindley and Teece 1997: 18).
8 “Due to recent advances in encryption technology, trade secrecy is now a more viable candidate for software protection than in the past” (Lipton 2006: 205).
9 Neither patent law nor copyright law requires disclosure of all source code (and underlying knowledge) to secure protection (Menell and Scrotchmer 2007: 1507). Bessen and Hunt (2007) found that most software patents are granted to large manufacturing firms in industries with a reputation for strategic patenting; only 5 percent were acquired by software publishers.
secrecy can also be used during the term of the patent and after its expiration (Ottoz and Cugno 2008: 143).

Entrepreneurs can also use contract law to secure their control (exclusivity) over knowledge assets. Contractual devices, such as confidentiality agreements with customers, special provisions (express nondisclosure clauses) in employment contracts, prior contracts (Yu 1981), technology licensing agreements and joint venture agreements, can effectively extend intellectual property protection and “propertize” knowledge assets (cf. Mackaay 1990: 899-900; H. Smith 2007: 1817). As we shall see, entrepreneurs use private-ordering rules to construct higher-level structures of property rights, such as standard-setting organizations, R & D consortia, patent pools and collective copyright licensing organizations (e.g. ASCAP), which encapsulate more complex combinations of the basic building blocks of intellectual property. Unlike property law, the regime of contract in modern market economies offers entrepreneurs a high degree of latitude in customizing the rights of parties to a contractual agreement. “Contract may be said ... to be the laboratory for what ultimately may be codified as fully fledged property rights” (Mackaay 1990: 901). It is the chief source of spontaneous rule systems.

In order to protect intellectual property, entrepreneurs also combine the above legal rules with non-legal rules, including technological rules, business and marketing rules, and social norms. In the very early stages prior to commercialization, entrepreneurs can adopt secrecy measures to provide initial control over information (Mackaay 1990: 900). They can also secure some measure of exclusive control of knowledge assets by means of physical technological “fences” of some sort, such as programmed copy protection, electronic “water marking” and encryption for computer software (Mackaay 1999: 252) and “potting” in the microprocessing industry (i.e. packing or physically obscurement of a product innovation in such a way that it makes it very
difficult to remove the packaging without destroying the product). Marketing techniques and tying arrangements can also be used, such as restricting regular software updates and online assistance to registered users (Mackaay 2002: 136). A famous example of business practices to secure IP protection include Coca-Cola’s rule about only very few employees (mostly executives) being privy to the secret formula for Coca-Cola Classic. Business strategies that emphasize lead-time and learning-curve advantages are of particular importance, including business techniques to slowdown competitors’ use of new technology. Another strategy is to make prior investments in certain complementary or cospecialized assets (e.g. requisite marketing services, manufacturing capacity) that must be used in conjunction with the technological know-how in question during production and commercialization of the innovation (Teece 1986: 285, 289). Entrepreneurs can also make use of norm-based systems of intellectual property. These systems “operate entirely on the basis of implicit social norms that are held in common by members of a given community” (Fauchart and von Hippel 2008: 187). (They found three strong norms related to the protection of recipes among French chefs.). In addition, in Japan, entrepreneurs used norms of trust combined with long-term employment to substitute for formal confidentiality agreements and trade secret law (Nakoshi 1993).
Table 2: Intellectual property rights as a multi-level pattern of capital

<table>
<thead>
<tr>
<th>Type of capital pattern (and level of order)</th>
<th>System description (elements and connections)</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macro</strong></td>
<td>Arrangement of all patents in the economy as a whole</td>
<td>Overall patent network in the United States</td>
</tr>
<tr>
<td>Overall capital structure in the economy ((L^4))</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Meso</strong></td>
<td>Patent pools among firms</td>
<td>MPEG-2 patent pool, DVD-1 patent pool, DVD-2 patent pool</td>
</tr>
<tr>
<td>Capital combinations within an industry ((L^3))</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Focal</strong></td>
<td>Patent portfolio at the firm-level (actually used in production)</td>
<td>Sony’s patent portfolio (more than 33,000 U.S. patents)</td>
</tr>
<tr>
<td>Capital combinations within a firm ((L^2))</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Micro</strong></td>
<td>Individual patents (potentially available for use in production)</td>
<td>E.g. Sony’s patent for a “Moving image compressing and recording medium and moving image data encoder and decoder” (US 5,343,248) which includes 10 claims</td>
</tr>
<tr>
<td>Capital goods ((L^1))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Matching the configuration of property rights to the nature of the technology, and ultimately, the constellation of end-user demand involves a process of trial and error-elimination over time. The learning process is very definitely not one of instantaneous discovery of a fully formed idea about how to configure property rights to protect a clearly defined technology, all of whose attributes are well known to the entrepreneur. Rather, entrepreneurial discovery is a dynamic problem-solving process that takes place in real time and under conditions of structural uncertainty (Harper 1996). Over time, entrepreneurs must try to adapt the combination of IP
rules that will add value to their productive ventures as technology and market conditions change. In order to hone appropriability mechanisms, entrepreneurs must actively experiment in a piecemeal fashion with the elements of the property rights mix. They must also improvise in response to the actions of competitors and adapt to changes in technology that result in existing “fences” becoming more permeable (e.g. “fence-cutting” inventions such as encryption circumvention measures). Changes in markets and technologies can lead entrepreneurs to adjust IP rules along one or more of three dimensions: ownership (i.e. type, number and identity of individuals), domain (i.e. scope of decision-making authority), or asset (i.e. asset size and quality) (Bell and Parchomovsky 2008). Entrepreneurs juggle property rights to achieve better combinations of number of owners, asset control and asset configuration (p. 1027).

2.4 Appraising capital combinations embodying intellectual property

As they create and adjust IP rule complexes, entrepreneurs engage in forward-looking evaluations of the net benefits of alternative capital combinations. This process is referred to as appraisal. These appraisals are acts of the mind (Lachmann 1977: 52). The appraisal constitutes a relationship between the evaluating mind and the capital combination evaluated; it does not inhere in the combination or its measurable attributes (p. 92, 156). In a capitalist economy, appraisals require an entrepreneurial mind-set oriented toward profit-and-loss accounting and the comparison of monetary costs and benefits. Capital combinations involving intellectual property are thus appraised according to the profit flows that they are expected to make. They are appraised according to the value of what they are anticipated to produce. “The value of goods of higher order [i.e. capital goods] is always and without exception determined by the prospective value of goods of lower order [i.e. consumption goods] in whose production they serve” (Menger 1950: 137; emphasis added). Entrepreneurial expectations are thus a crucial part of any appraisal
because the appraisal is undertaken at a point in time when the corresponding lower-order goods are still yet to emerge in the future (Garrison 1990: 138). Given the heterogeneity of their expectations and circumstances, different entrepreneurs will have different valuations of the same capital good or capital combination. Any given entrepreneur’s appraisal depends on “who s/he is, what s/he knows and whom s/he knows” (Sarasvathy and Dew 2011: 14). In the context of intellectual property, it is most unlikely that the same patent or patent portfolio would receive the same appraisal by different entrepreneurs because a patent’s value is highly dependent upon local context of use: “The worth of a patent ... depends upon who wants to use it, for what commercial or other purpose, in what market (or litigation setting), and under what set of economic and legal constraints” (Phelps and Kline 2009: 168).10 The particular purposes to which entrepreneurs put patents depend not only upon their expectations about the future but also on their “subjective judgement of the relevance of past experience, subjectively interpreted, to this future” (Lachmann 1971: 39). In their appraisal of IP combinations, entrepreneurs also try to take account of the plans of other entrepreneurs whose future actions complement or compete with their own because they will influence the value of the lower-order goods to be generated (Lewin and Baetjer 2011: 341). Thus, appraisals involve forming guesses about others’ perceptions of patent value and hence the interaction of entrepreneurial minds (heterogeneous mental models):

Owners and users [of patented technology] may ... draw inferences about each other's perceptions of value from observing willingness or reluctance to incur costs in asserting or clearing rights. Patent owners decide how much to spend monitoring infringements and asserting their rights, thereby signaling how valuable they consider their patents to be. Users give signals about the value that they place on technology through their responses to

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10 For a brief examination of current practices for valuing patents, see Kelley (2011: 123-129).
assertions of rights [i.e. assertions of patents against users by patent owners] and through their own investments in patent searching and clearing rights. These signals may help owners and users to decide when bargaining over licenses is worthwhile.

(Eisenberg 2011: 66)

Furthermore, in the portfolio-driven era of patenting, entrepreneurs base their patenting decisions upon appraisals, not of individual patents in isolation, but of the synergistic benefits of large portfolios of complementary patents (Parchomovsky and Wagner 2005). It is to the theme of the emergent properties of patent pools that we turn in the next section.

3. Patent pools as emergent combinations of property rights at the meso level

A patent pool is an organization set up to combine multiple patents owned by multiple entities into a single portfolio.\(^\text{11}\) The patents are bundled into a single licensing package that is offered to pool members and third parties. The relevant patent holders are usually for-profit firms, but not exclusively (e.g. Columbia University is a member of the MPEG-2 patent pool). Though differentiated, the patents are related by significant technological properties, whether product- or process-based. In effect, patent pools enable a collection of firms “to combine their patents \textit{as if} they were a single firm” (Lampe and Moser 2011: 1; emphasis added).

In terms of the taxonomy in Table 2, a patent pool is a planned organization. It is a deliberate creation of relatively few individuals and relies upon formal organized enforcement. It is a purposeful combination of individual patents. Although it is embedded within an abstract system

\(^{11}\) “Patent pool” is not actually a legal technical term, so its meaning is not defined by law (United States v. Line Materials, 333 U.S. 287, 313, n.24 (1948) in Klein 1997a: 3). A patent pool is different from cross-licensing, in
of general legal rules of property, a patent pool is constituted and maintained by rules of organization and specific commands that are relatively concrete and oriented toward specific common goals, such as licensing and commercialization of a new technology. For instance, the MPEG-2 pool, which we examine in the next section, was originally created through a network of four formal agreements among nine companies that established boundary rules (e.g. rules specifying how patent holders enter and leave the pool, and procedures for adding and removing patents from the portfolio), position rules (e.g. rules specifying the different roles of the independent licensing administrator, licensors and licensees), authority or choice rules assigning action possibilities to each position and determining the level of decision-making control, scope rules (e.g. rules delimiting the portfolio license’s authorized fields of use), information rules governing who communicates what with whom, and payoff rules (e.g. rules specifying the amount and allocation of royalties).  

12 which firms agree bilaterally to license their intellectual property to each other and retain control over it (Grindley and Teece 1997: 326).

12 The classification of rules in this paragraph draws upon Ostrom et al.’s (1994) study of rules, games and common-pool resources. For ease of exposition, the scheme here subsumes aggregation rules into the category of authority rules (which Ostrom later refers to as choice rules).
### Table 3: Types of intellectual property rule-systems

<table>
<thead>
<tr>
<th>Nature of rule system</th>
<th>Orders (i.e. systems of abstract, end-independent rules)</th>
<th>Organizations (i.e. systems of concrete, end-dependent rules)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spontaneous</strong></td>
<td>Common law of trade secrets</td>
<td>Codification and harmonization of trade secret law of different states (Uniform Trade Secrets Act)</td>
</tr>
</tbody>
</table>
|                       | Copyright at common law (independent of statute)       | Federal statutory intellectual property regimes (e.g. Patent Act 1952, America Invents Act 2011, Copyright Act 1976, Copyright Term Extension Act 1998 (“Mickey Mouse Protection Act”, “Sonny Bono Act”))
|                       | Common law of publicity rights (relating to commercial use of one’s identity or persona) |                                                                 |
|                       | “Shop right” doctrine                                 |                                                             |
|                       | Norm-based intellectual property systems (e.g. norms protecting recipes of French chefs) |                                                             |
|                       | Norms of trust and life-time employment               |                                                             |
| **Planned**           | Open source software development projects (e.g. Apache web server, Linux operating system, Perl) | Patent pools |
|                       | Standard-setting organizations                        | Bilateral cross-licensing agreements |
|                       | Secondary markets in patents (including online auctions) | Patent portfolio under a single firm’s control (e.g. Qualcomm, Lucent, Thomson, Intermec Inc.) |
|                       | Clause in US Constitution on patents                   | Prior contracts: development contracts, patent licenses, employment contracts (making assignment of patent rights a condition of employment; non-compete clauses) (Yu 1981) |
|                       |                                                         | Confidentiality agreements |
|                       |                                                         | Digital Rights Management (DRM) |
|                       |                                                         | Industry associations for protecting intellectual property (e.g. to protect plant variety rights in France 1904-1970 (Hermitte 1988)) |

**Source:** The dimensions of classification of the table, but not its content, are derived from Vanberg (1989) and Langlois (1992, 1995)

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13 Statutory intellectual property regimes are classified here as spontaneous organizations (upper right-hand cell) rather than planned organizations because they have changed so frequently in ways that could not have been anticipated by their founders, giving their evolution an organic character over long time periods. O’Connor (2011: 101, 104, 106) suggests that both the patent system and copyright systems were designed for one purpose but were later exapted for other uses. In particular, he conjectures that the first patent system arose in 15th-century Venice as a means for the rulers of the city-state to restrict the level of economic and de facto political power that craft guilds had secured during the late medieval period. Similarly, copyright was originally intended to provide incentives for entrepreneurs to set up printing shops to publish and disseminate useful printed matter rather than to protect the rights of authors in their artistic self-expression.
Although a patent pool results from a well-articulated plan and purpose, there is a sense in which the patent pool, as a meso-level technological platform for multiple industries, becomes a system of rules characterized by an *intermediate* degree of abstraction (in the sense of Whitman 2009). The patent pool fills the gap between end-independent abstract rules and specific concrete purposes. It abstracts from the details of numerous small-scale bilateral licensing contracts to provide a common point of orientation (i.e. a portfolio license) for a large number of users of patented technology (cf. Lachmann 1971: 49-50; Tulloh and Miller 2006: 95). The MPEG-2 patent pool, for instance, provides a stable orientation scheme for over 1400 licensees. It thereby facilitates the coordination of diverse concrete purposes of these licensees, ranging from television broadcasting based on MPEG-2 to consumer-electronics manufacturing for DVDs and digital TV. We do not know beforehand by whom and in what way the licenses will be used. Third parties can use the rules to help them predict the behavior of those with whom they interact and reduce the likelihood of infringing others’ patents and subsequent litigation.

The creation of a patent pool meets all the preconditions that Menger (1950) identified for capital formation. The patents are available in the present for combination in future time periods; they possess real properties that bestow causal powers and they are capable of being organized in a production process; individuals have command over potentially complementary patents for an extended time period; and individuals have knowledge of causal connections between patents and the satisfaction of human needs (Harper and Endres 2010: 33).

Patent pools are an excellent example of how the capital structure interpolates new levels of organization within itself as it differentiates and evolves. The patent pool is an interpolation of a new meso-level of economic organization within the macro IPR structure. See Table 2. Patent pools are emergent networks of related patents within a technological field. They possess
emergent properties and produce significant synergistic effects. For example, they improve qualitative coordination of complementary activities by helping parties to link and mesh their expectations and production plans (cf. Langlois and Foss 1999: 206), they reduce the transaction costs of patent licensing, speed up the adoption and diffusion of new technology, avoid litigation and the losses from conflicting patents. “For patents, the whole is greater than the sum of its parts. The true value of patents inheres not in their individual worth, but in their aggregation into a collection of related patents—a patent portfolio” (Parchomovsky and Wagner 2005: 5-6). Parchomovsky and Wagner (2005) identify a dozen emergent effects from purposeful combinations of distinct but related individual patents, including facilitating subsequent in-house innovation, coordinating related technological developments, avoiding costly litigation, improving bargaining and defensive positions with respect to competitors, enhancing ability to attract capital investment, reducing uncertainty related to technological, competitive and market developments, and increasing voice in the politics of the patent reform and reducing uncertainty in patent law. The strategic advantages of patent portfolios are more than just additive. “The broader protection conferred by patent portfolios offers a range of benefits to the holder different in kind as well as size from a simple collection of unrelated patents” (Parchomovsky and Wagner (2005: 33).

Patent pools fulfill all the formal conditions for emergence that economic patterns must satisfy to qualify as emergent phenomena (Harper and Endres 2011): (1) material realization (patent pools are realized in physical structures and processes)\(^{14}\); (2) coherence (patent pools are not a mere aggregate but a systemic whole); (3) non-distributivity (a patent pool possesses global qualitative coordination properties absent from its parts); (4) structure dependence (their systemic properties
depend upon the connective structure and organization of patents and other rules. In addition, patent pools exhibit extra-strength versions of diachronic and synchronic emergence, which require that patterns possess one or more additional features: (5) **genuine novelty** (a patent pool is a genuinely novel structure that is qualitatively different from the individual patents from which it emerges); (6) **unpredictability in principle** (as the first patent pool in US history, the Sewing Machine Combination (1856-1877), could not be predicted or logically deduced through a rational procedure); and (7) **irreducibility** (the systemic properties of a patent pool, such as its economic value, do not follow from the properties of individual patents in isolation or in smaller, simpler patent portfolios). “The value of a well-designed portfolio will always exceed the sum of the values of the individual patents” (Parchomovsky and Wagner 2005: 58).

A patent pool is not a mere aggregate (i.e. stock) of patents. It consists of patents in relations to each other. The properties of a patent pool depend critically upon how it is organized and how its elements interact. Patent pools have internal structure. Patents stand in relations to one another, and these relations have a direction. If \( a \) and \( b \) are two non-identical patents, the state of affairs \( a \) blocks \( b \) is quite different from the state of affairs \( b \) blocks \( a \). In the case of the aircraft manufacturers’ pool established in 1917, for instance, the Wright brothers’ patent (issued in 1906) for their wing-warping mechanism could block the production of planes using Glen Curtiss’s patented improvements (issued in 1916), but the Curtiss patent did not block the production of planes using the Wright patent, provided production did not include Curtiss’s patented wing flaps (Bittlingmayer 1988). The complementarity relation that exists between patents in a pool is not limited to the capital combination of a single firm. It should also be noted

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14 According to Cheung (1982: 49), a key element of the patent system is an “observability conversion”. In order to protect an idea with a patent, it is necessary to convert the idea into an observable product or process and to draft a patent claim that sets boundaries for the idea.

15 “There is no historical evidence to suggest that the sewing machine pool was anticipated” by the members (Lampe and Moser 2010: 902).
that patent pools themselves can stand in relations of complementarity. For example, the DVD standard comprises two mutually exclusive patent pools. In order to manufacture products compliant with the DVD standard, entrepreneurs need to obtain licenses from both pools (Layne-Ferrar and Lerner 2011: 295). Hence the two pools are complementary to each other in production. Furthermore, these two pools are also complementary to the MPEG-2 pool.

4. MPEG-2 case study

The MPEG-2 patent pool assembles key patent inputs required to produce consumer electronics products embodying MPEG-2 technology. MPEG-2 is a technology for compressing, transmitting and storing digital video and audio data (Watkinson 1999). It is the technical standard for digital television and is also used for encoding movies on DVDs. “MPEG” stands for the Motion Picture Expert Group, a working group of the International Organization for Standardization (ISO) in charge of developing technical standards for coded representation of digital audio and video data. The MPEG working group (not to be confused with the MPEG-2 patent pool or its licensing administrator) sets technical standards and does not per se deal with intellectual property rights.
Table 4: Systems-theoretic characterization of the MPEG-2 patent pool

<table>
<thead>
<tr>
<th>Feature</th>
<th>MPEG-2 description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composition (elements)</strong></td>
<td>Patents deemed essential for implementing the MPEG-2 protocol, which is the basic transmission syntax (and semantics) for digital television. An essential patent is “any Patent claiming an apparatus and/or method necessary for compliance with the MPEG-2 Standard under the laws of the country which issued or published the Patent” (Carlson 1999: 371).</td>
</tr>
<tr>
<td></td>
<td>The pool began as an agreement among nine patent holders, spread over three continents, to combine 27 patents required to meet the MPEG-2 standard (Merges 1999: 28). The MPEG-2 LA pool now contains more than 900 patents worldwide from 27 different companies (MPEG-LA 2011).</td>
</tr>
<tr>
<td></td>
<td>Patents cover five major technological components (modules) of the MPEG-2 protocol for spatial encoding, motion compensation, picture sequence, bit rate control, and systems (Carlson 1999: 370).</td>
</tr>
<tr>
<td><strong>Structure (connections)</strong></td>
<td>The original patents included in the portfolio are readily categorized as blocking and/or complementary: the portfolio combines patents that an independent expert had determined to be essential to compliance with the MPEG-2 standard. There was no technical alternative to any of the portfolio patents within the standard: “Each portfolio patent is useful for MPEG-2 products only in conjunction with the others” (Klein 1997b: 9-10).</td>
</tr>
<tr>
<td></td>
<td>As the pool expands, the relation between the patents becomes more attenuated. As the pool grows rapidly, new patents included may be blocking or complementary to certain of the pool’s patents, but not blocking or complementary to the pool as a whole. As the patent pool grows, it runs the risk of losing cohesion and incorporating patents over products that would compete with the pooled technologies (Carlson 1999: 390).</td>
</tr>
<tr>
<td></td>
<td>External structure: long-term contractual relations between the licensees and the pool.</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>General property and contract law</td>
</tr>
<tr>
<td></td>
<td>Patent law</td>
</tr>
<tr>
<td></td>
<td>Antitrust regulation of patent pools</td>
</tr>
<tr>
<td></td>
<td>Patent Office</td>
</tr>
<tr>
<td></td>
<td>Courts and regulators determine the enforceable scope of patents (C99: 366, 373)</td>
</tr>
<tr>
<td></td>
<td>Standard setting organizations and associated working groups, e.g. ISO, IEC, MPEG Working Group 11. Competition from other technologies, actual and potential. Licensees, actual and prospective (Carlson 1999: 371)</td>
</tr>
<tr>
<td><strong>Mechanism (formation process)</strong></td>
<td>Planned mode of origin.</td>
</tr>
<tr>
<td></td>
<td>The pool was an outgrowth of the creation of the MPEG-2 standard formed in 1994. The three-part standard of MPEG-2 (Systems, Video and Audio) was elevated to international standard status in November 1994 (Merges 1999: 29). Key patent holders met to try to establish a voluntary licensing entity to which they would contribute licensing rights. They formed a working group which then researched nearly 9,000 patents, looking for those essential to the MPEG-2 standard (Chartrand 1997).</td>
</tr>
</tbody>
</table>
Formed in 1997, the MPEG-2 patent pool heralded the beginning of a new era in patent pools. It was the first of a “new hybrid breed” of patent pools that is less comprehensive than the auto and aircraft “mega-pools” of yore (being focused only upon one technology rather than all patents in an industry), but is more enduring and robust than small “contract-based pools” based on simple cross-licenses (Merges 1999: 28). It was also the first time that the Antitrust Division of the Department of Justice had approved a patent pool in a business review letter (Klein 1997b). “This is definitely a first in recent history, and likely a first on patent pooling” (Bill Brooks, DoJ spokesman; in Chartrand 1997).

4.1 Remodularization

In effect, a patent pool combines the rights to exclude of many individual, closely related patents and thereby provides the pool with a “broad sweep of exclusivity” (i.e. broad-based IP protection) in a particular technological field (cf. Parhomovsky and Wagner 2005: 7, 34). Individual patents only give patent owners rights of exclusion, not affirmative rights to use their intellectual property (Kieff and Paredes 2004: 188).16 Patents rights do not confer any positive entitlements for their owners. “Ownership of a patent does not entitle one to do anything, including making the invention. Patent ownership only allows the owner to stop others from doing certain acts without the owner’s permission” (Hays 2008: 502). In particular, the patent gives its owner the legal right to exclude others from making, using, selling or importing a product or service embodying the claimed invention in the absence of a license (Geary 2009: 98).

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16 Hence, it is a mistake to say, as does Kitch, that a patent confers “the exclusive right to make, sell and use an invention for a limited term” (Kitch 1998: 13). The uses to which patent holders can put their intellectual property are determined by other areas of law, such as criminal laws and public safety laws (Kieff and Paredes 2004: 188).
The patent holder has the right to exclude others from the scope of the claims of the patent. “The claims of a patent are its boundaries, defining the scope of exclusion” (Chiang 2010: 523).¹⁷

The creation of a patent pool thus involves rebundling existing patent rights and forming new connections among them. In our capital-theoretic framework, such a reshuffling of entitlements to knowledge assets constitutes a form of capital regrouping. It results from an entrepreneurial process of “remodularization” that specifies a new architecture of intellectual property rights and a new set of interfaces between owners and potential users of knowledge assets (cf. Langlois 2002).

A patent pool creates a sort of “shell” (i.e. module) in the computer-science sense of the term in that it generates a well-defined boundary and interface between the internal workings of the pool and the external environment with which the pool interacts (cf. Alcorn and Toledo 2000: 218). “Orders do not merely have boundaries, ordering processes create boundaries. Things are what they are by separating themselves from other things” (Waldenfels 2004: 71-86).¹⁸ In the case of the MPEG-2 patent portfolio, the boundary of the pool encapsulates a significant proportion of the essential patents required to practice the MPEG-2 standard. The *sine qua non* of an essential MPEG-2 patent is that it is a “trespass across the property bounded by those four corners ... defined by the MPEG-2 standard” (Horn quoted in Clarkson 2004: 39). The pool boundary also places many interactions and negotiations among the relevant patent holders within a single

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¹⁷ The claiming system of patent law requires patentees (i.e. patent holders) to articulate the boundaries of their invention by the time of patent issuance, usually by listing the necessary and sufficient characteristics of the invention (Fromer 2009). The claims comprise technical descriptions of the process, machine, method, or matter contained in the original patent application (Besen and Raskind 1991: 7). Patent boundaries are malleable, however, in that claims can be changed throughout the life of the patent, thereby shifting the patent boundary (Chiang 2010). The scope of the exclusion right of an individual patent depends upon legal rules of “patent claim construction” (i.e. the methodology for interpreting the patent’s meaning) (Kieff and Paredes 2004).

¹⁸ All complex adaptive systems have a layered structure of boundaries enclosing boundaries. Boundary formation is an essential part of selective processes of adaptation: “Without boundaries there cannot be individual histories, and
module. This boundary is not fixed once and for all, but provisional, mutable, incomplete and semi-permeable (cf. Chick and Dow 2005: 372-373, 376).

The interface of the MPEG-2 patent pool connects the pool in very specific ways to the larger IP ecosystem and the market order. It limits the type of transactions, interactions, energy flows and knowledge flows that occur across the pool’s boundary. Potential users, such as manufacturers of DVD recorders and DVDs, can obtain a portfolio license from the MPEG-2 pool in a single transaction in order to obtain access to core patented technology. Instead of negotiating royalty rates, scope of license, grant-back conditions and duration with many separate patent holders, the licensee pays just one fee for a standardized licensing package to the pool licensing administrator (MPEG LA). MPEG LA offers one and the same portfolio license to everyone. There is no customized subdivision of the package license: “Since each patent [in the pool] is essential, the royalty rate ... is the same whether a licensee uses one or more patents. The license, in effect, conveys the intellectual property necessary to enter the field” (Futa 2002: 5).

The interface (such as MPEG LA’s website) markets and promotes the services of the capital combination created by the MPEG-2 patent pool. It communicates to the market precisely what is in the MPEG-2 portfolio license and what is not. It signals to the market who has complementary inputs (and invites those who might own essential patents to submit them for evaluation and potential inclusion in the pool). The interface of the licensing scheme economizes on information: potential licensees do not need to know all the details of how the pool operates; they just need to know enough about the coverage and terms of the MPEG-2 license (including royalty payments and restrictions on the field of use of the license) to be able use the license for

without individual histories selection for fitness is not possible. Thus, Darwinian selection depends upon the origin and development of boundaries” (Holland 2006: 6).
their own purposes. The interface makes the portfolio license meaningful to potential users.\textsuperscript{19} The fact that the MPEG-2 pool is a complex capital combination constructed “bottom up” from familiar forms of intellectual property (i.e. patents) facilitates the process of intersubjective understanding: “A complex of property rights [e.g. a patent pool] built from a small number of standard building blocks [e.g. patents] is likely to be easier for third parties to process than functionally equivalent complex property rights for which third parties must figure out the nature of the building blocks” (Merrill and Smith 2000: 37). By reducing the level of scrutiny required, standardized building blocks facilitate interpretation of the portfolio license and make it easier to decide whether to become a licensee. To be meaningful, the portfolio license must encapsulate a large share of the essential patents needed to practice the particular patented technology. The interface explains how potential licensors and licensees can ask for services and classifies the messages to which the pool administrator will respond (cf. Tulloh and Miller 2006: 103, 112). As an “abstraction boundary”, the patent portfolio license encapsulates a common solution to a recurring problem and repackages it for reuse with multiple licensees (cf. Langlois 1999; Tulloh and Miller 2006: 90). It is thus characterized by an intermediate degree of abstraction in that it lies in the middle ground between highly specific contract rights (limited to particular persons in an idiosyncratic deal), on the hand, and highly general rules of property pertaining to all persons in all circumstances, on the other (Whitman 2009). The license agreement is a form of “congealed knowledge” about effective business practices (“ways and means”) for carrying out productive tasks (Veblen 1908). It embodies knowledge (standardized legal solutions) about procedures for guaranteeing the implementation of complex licensing agreements and for resolving disputes. The MPEG-2 patent portfolio licensing agreement itself takes advantage of modularity by making use of “boilerplate” provisions that handle recurring issues. For instance,\textsuperscript{19}

\textsuperscript{19} “A license is an expression of a patent owner’s giving permission to another to exercise one or more of the exclusory rights, following the general form: ‘If you, the licensee, do any of the acts listed herein and pay me, the
the severability provision (7.10) states that if a court finds any provision of the agreement unenforceable, the remaining provisions will remain in full force, thereby immunizing the contract as a whole from the failure of one of its parts (cf. Smith 2006: 1194). The MPEG portfolio license also becomes a focal point for certain types of transactions around which potential users can orient their production plans. This is evidenced by the fact that MPEG-2 licensees have generally been unwilling to pay Lucent, who originally did not join the pool, more than the per-patent royalty rate charged by MPEG-LA for licenses to Lucent’s MPEG-2 patents (Lerner and Tirole 2008: 185).

The patent pool repartitions rights, repackages them into new parcels and allocates them among the relevant parties. It loosens the connections between residual control rights of the patent holders and decision rights over their patents. The patent holders in the pool retain their high-level residual rights of control over their intellectual property (including the right to offer independent bilateral licenses outside the pool), but they grant the licensing administrator the necessary legal rights to be able to license their patents to third parties over the useful life of the patents (Futa 2002: 1; Horn 2003: 121). The patent pool thereby coalesces day-to-day decision rights into the hands of the licensing administrator (MPEG LA) that has a comparative advantage in managing the licensing of intellectual property. It effectively moves decision rights to those with the superior knowledge and expertise in making decisions over access to the package of knowledge assets. Although the licensing administrator is not a patent owner, it has de facto control over the diffusion of the patented technology and can capture economies of specialization and of scope in administering this and other portfolio licenses for other patent pools.
4.2 Formation process

The formation of the MPEG-2 patent pool took place against a backdrop of strict property rules.\textsuperscript{20} Anyone wanting to buy (or license) the patent right must bargain to a mutually agreed price (or royalty) with the current patent owner. Like other entitlements backed by property rules, patents provide a set of high-powered enforcement options, including shutdown injunctions and enhanced (i.e. supracompensatory) damages, to deter transfers of entitlements without the owner’s consent (Kieff 2008: 5). After a finding of patent validity and infringement, the patent holder is allowed to enjoin (i.e. prohibit) infringement of the patent by means of a legal injunction.\textsuperscript{21} The credible threat of “production-choking injunctions” (Merges 1999: 21-22) played an important role in the formation of the patent pool. The threat not only constrained unproductive rent-seeking behavior (i.e. uncompensated transfers of entitlements) but also created the possibility for productive behavior (Langlois and Foss 1999: 202).

The formation of the MPEG-2 patent pool was a protracted process, taking over three years. This timeframe is still less than that for at least one other recent pool. The patent pool for radio frequency ID technology (RFID) took five years of negotiations (Ray 2010). The various stages in setting up the pool are described in Table 5.

\textsuperscript{20} Property rules are here understood in the classic sense defined by Calabresi and Melamed (1972). “Property rules establish boundaries on the resources that can be secured for private use and those that must be shared with others, establishing the basis for claims to the value created by resources” (Hadfield 2011: 11).

\textsuperscript{21} The most dramatic example in recent years was the threat of an injunction to shut down Research In Motion’s Blackberry e-mail service for infringing NTP’s patents. The patent dispute was settled in 2006 when RIM paid NTP $612.5 million in a “full and final settlement of all claims” (Settlement reached in BlackBerry patent case: http://www.msnbc.msn.com/id/11659304 ).
Table 5: Timeline of milestones in the formation of the MPEG-2 patent pool

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>Moving Picture Experts Group (MPEG) is established. This working group is convened under the joint supervision of the International Organization for Standardization (ISO) and the International Electro-technical Commission (IEC). MPEG is officially Working Group 11 (WG 11). Its formal name is ISO/IEC JTC 1/SC 29/WG 11. Its mandate is to develop standards for coded representation of digital audio and video and related data (MPEG IPR Backgrounder 1994).</td>
</tr>
<tr>
<td>1993 (July)</td>
<td>MPEG Intellectual Property Rights (IPR) Working Group formed. This group of licensing experts is outside of MPEG and is not an ad hoc or another form of MPEG activity (Resolution 3.9.6 of the New York MPEG meeting in July 1993). MPEG adopts a resolution recommending that WG 11 support an initiative leading to the establishment of a patent pool for MPEG-2, outside of MPEG.</td>
</tr>
<tr>
<td>1993 (September)</td>
<td>MPEG IPR Working Group begins developing its plan for dealing with the MPEG intellectual property rights issue (CableLabs 1994).</td>
</tr>
<tr>
<td>1994 (3/24/94)</td>
<td>At the Paris meeting in March 24th, 1994, MPEG IPR Working Group reaches a consensus on a two-phase action plan for establishing a licensing entity (CableLabs 1994). MPEG IPR Working Group meets in Paris and is attended by representatives of more than 50 companies who are among the manufacturers and users of digital compression technology worldwide. Efforts begin to form an MPEG-related licensing entity (CableLabs 1994).</td>
</tr>
<tr>
<td>1994 (September)</td>
<td>MPEG IPR Working Group meets again to discuss the specifics for an MPEG licensing entity (Krause 1994). [Check ???]</td>
</tr>
<tr>
<td>1995 (3/23/95)</td>
<td>MPEG IPR meets in Lausanne, Switzerland and reaches a consensus on a plan for establishing a licensing entity.</td>
</tr>
<tr>
<td>1995 (3/27/95)</td>
<td>CableLabs announces that an MPEG-related licensing entity (i.e. a voluntary patent pool) will be formed to provide efficient access to intellectual property rights necessary for the implementation of MPEG technology worldwide (CableLabs 1995).</td>
</tr>
<tr>
<td>1996</td>
<td>MPEG LA is formed, with 9 members and 25 patents</td>
</tr>
<tr>
<td>1997 (April)</td>
<td>MPEG-LA submits a letter to the U.S. Department of Justice requesting a formal review and approval for the patent pool.</td>
</tr>
<tr>
<td>1997 (June)</td>
<td>Business review letter from the Department of Justice gives clearance for the formation of the MPEG-2 pool.</td>
</tr>
<tr>
<td>1997 (July ???)</td>
<td>MPEG LA licensing program begins after final approval is granted from the U.S. Department of Justice</td>
</tr>
<tr>
<td>2012 (January)</td>
<td>MPEG-2 patent portfolio covers 27 patent owners, and more than 900 patents worldwide</td>
</tr>
</tbody>
</table>
Several characteristics of the formation process are particularly relevant to a capital-theoretic perspective on intellectual property. These are: the role of sophisticated lead users in initiating the creation of the MPEG-2 patent pool; the use of common plan as an orientation point to guide interactions during pool formation; and the role of a small group of independent experts in screening patents for potential inclusion in the pool. We discuss each of these characteristics in turn.

As for the first characteristic, the driving force behind the formation of the MPEG-2 patent pool was provided by neither consumers nor patent holders but by sophisticated lead users of the patented technology. The idea for a patent pool originated within Cable Television Laboratories (hereafter “CableLabs”), a non-profit R & D consortium of cable television system operators (CableLabs 1997). Although CableLabs owns over two dozen patents, it does not hold any essential patents for the MPEG-2 standard. CableLabs met all of von Hippel’s (1996, 2005) criteria for qualifying as a lead user: as the research arm of the cable-TV industry, it was at the forefront of emergent market and technological trends, its members experienced strong needs that would later become more general in the future, and they expected major benefits from using the new technology in terms of increased services (quality, security and interactivity) and lower video distribution costs. The MPEG-2 standard enabled cable-TV operators to exploit the untapped capacity of their existing capital structure—namely, the higher bandwidths (data rates) available to deliver higher image resolution and picture quality to their customers (MPEG IPR Backgrounder 1994: 1).

More specifically, the pool was the brainchild of Baryn Futa, the chief operating officer of CableLabs at the time, who came up with the idea while convening and chairing the MPEG
Intellectual Property Rights (IPR) Working Group (Yoshida 1997). Through his chairing of that working group, Futa was in effect an intermarket operator who made connections between users and patent holders of the MPEG-2 standard (MPEG #42). He and other members of the MPEG IPR Working Group could see that there was a major gap between what was available (the current structure of property rights) and what could be achieved (the potential restructuring of essential patents into a patent pool). They saw that patent thickets stood in the way of providing end-users with a more enjoyable digital media experience. “The entrepreneur is the agency that prevents the persistence of a state of production [and we might add, a structure of property rights] unsuitable to fill the most urgent wants of the consumers in the cheapest way” (Mises 1966: 335-6; see too p.708).

Futa was what Burt (2002, 2004) calls a “between-group broker” who bridges “structural holes” in the social structure of the market. As chief operating officer at CableLabs, his primary constituents were cable operators, but in his capacity as chair of the MPEG IPR Working Group he worked alongside a global group of hardware manufacturers (Voorhees 1995b). He thereby built valuable interpersonal bridges between disconnected parts of the market. “Structural holes are an opportunity to broker the flow of information between people and control the projects that bring together people from opposite sides of the hole” (Burt 2002: 155). A structural hole was active because MPEG-2 patent holders wanted to generate a healthy return on their investment in R & D, whereas cable operators and other purchasers want to keep the cost and royalties as low as possible (Voorhees 1995b; Yoshida 1997). By establishing processes that built trust and reputation, Baryn Futa corralled intensely independent patent holders (mainly hardware manufacturers) into a cohesive group and managed to build a consensus for a voluntary patent pool that employed a traditional royalty model for licensing MPEG-2 patents (Voorhees 1995a, 1995b).
This brings us to the second characteristic of the formation process—the use of a common plan as an orientation point to guide interactions during pool formation. The MPEG IPR Working Group agreed to a two-stage action plan for establishing an MPEG-related licensing entity. This common plan served as an “orientation map” for other participants, including patent holders, manufacturers and lead users of digital compression technology. The making of this plan was not only an observable event, it was also documented and made available for public scrutiny in press releases, newsletters and over the Internet. The plan identified the actual ends, means and obstacles (negative means), to which participants could orient their actions. The common goal was to establish a licensing entity whose mission was to foster reasonable and nondiscriminatory access to intellectual property rights necessary for global implementation of digital television (MPEG IPR Backgrounder 1994: 2).

In addition to providing points of orientation for guiding the actions of multiple parties, the plan also contained specific directives for action in time. The first phase of the plan involved identifying which patent holders were willing to participate in an MPEG-2 licensing entity and then determining whether they owned patents necessary for the implementation of core MPEG-2 technology. Accordingly, companies were asked to complete a form letter indicating their interest in working toward setting up a licensing entity and providing an annex of their own relevant patents. The second phase of the plan involved determining the licensing entity’s administrative structure and the allocation of royalties (Krause 1994).

Which brings us to the third characteristic of the formation process: the role of independent experts in trying to generate a list of patent owners who might have essential MPEG-2 patents. With financial resources from CableLabs, Futa recruited Ken Rubenstein, an independent patent
attorney, to undertake a worldwide review of MPEG-2 patents and patent abstracts.\textsuperscript{22} “The study simply identified people that were worth targeting in order to try to persuade them that this was a cooperative effort worthy of their involvement... It was a fishing expedition to try and cast a wide net to try to find out what might be essential” (Horn, quoted in Clarkson 2004: 40-41). In four years, Rubinstein and his partner studied more than 8000 US patent abstracts, 800 US patents and 80 patent prosecution histories (Yoshida 1997).

Screening the patents involved a process of subset selection (Hodgson and Knudsen 2006: 479-482). As the name implies, subset selection involves selecting a subset of patents from an anterior set. The anterior set was the group of patents at the disposal of the independent expert when making his formal determination of their essentiality. The anterior set did not comprise all MPEG-related patents; it only included those patents submitted by their owners for a formal evaluation. Unlike Darwinian “generative selection”, subset selection does not create new variation at the level of the individual patents in the pool. In fact, subset selection actually reduces variation – each successive round of subset selection transforms the anterior set of heterogeneous patents into a smaller posterior set of essential MPEG-2 patents. Hence, subset selection is a contraction mapping (Hodgson and Knudsen 2006: 479, 481). Subset selection involved the selection criteria and deliberate choices of the patent attorney and did not exclude human intentionality. The independent attorney rejected patents in the anterior set that were not essential to the practice of the MPEG-2 standard. The selection process thus changed the composition of the class of patents but held constant the properties of the individual patents (because an individual patent possesses relatively stable characteristics) (Hodgson and Knudsen 2006: 479).

\textsuperscript{22} Without funding from CableLabs, the project would never have come to fruition: “No CableLabs, no pool” (Futa, quoted in Yoshida 1997).
5. Conclusions

Even if some property rights are created and granted by the state, entrepreneurs in the market are the ultimate arbiters of how property rights are applied and used in production. Entrepreneurs are the major causal agents in the transformation of legal rules-in-use and their actions form and change production complementarities between legal rules. Legal rules do more than just structure exchange relationships among economic agents. They are an integral part of the productive capabilities of the economic system and participate in productive processes. They are part of the knowledge structure that captures energy to select, transport and transform materials into new forms (cf. Boulding 1978). Like all capital goods, property rights are combinatorial, relational, structural and heterogeneous. Entrepreneurs mix and match legal rules and property forms and combine them with other types of rules (including norms and technological rules) in order to protect knowledge assets and organize production. Entrepreneurs identify gaps in the meshing of the capital structure. Because they face structural uncertainty, new combinations of rights are seldom if ever perfect. The making of new combinations precedes their selection by the market and their matching with the needs of consumers. Entrepreneurs continually reshuffle property rights in response to changes in technology and market conditions. They create more complex structures of property rights by means of sequential adjustments in capital combinations and rule complexes. Like other capital patterns, the property rights structure undergoes continuous transformation as a result of these piecemeal entrepreneurial experiments. Thus, in the capital-theoretic approach, the network of entrepreneurs’ production plans determines the overall shape of the property rights structure.
Theories of property rights that ignore multilevel patterning and the interactions of phenomena at different temporal and spatial scales are going to be deficient. We have shown that the idea of modularity is useful for reexamining the nature of property rights in general and the structure of intellectual property rights in particular: “The creation of ‘new’ rights and the rebundling of existing rights are really manifestations of the same underlying process of modularization, remodularization, and sometimes even demodularization” (Langlois 2002: 27). A production module (the capital combination) rather than an exchange relation (the transaction) forms the basic unit of the analysis. Unexpected changes in productive processes always imply remodularization and regrouping of property rights. They entail changes in encapsulation boundaries, revisions in the modular decomposition of entitlements, and changes in connections and levels of property rights.

The interpolation of new levels of property rights (such as patent pools) arises from specific combinatorial acts that create capital. It occurs as a byproduct of capital formation. The combinatorial creation of patent pools comforms to what Abler (1989) calls the “particulate principle” of self-diversifying systems. This principle maintains that generative recombination of system elements must be based on regrouping particles rather than on blending constituents. Adaptive processes of self-organization and selection in the patent system are based upon dynamically stable discrete units (forms of intellectual property). Even after they are combined into higher-level structures, such as patent pools, the original patents (i.e. the “particles”) continue to be identifiable perceptually rather than blend with each other (Abler 1989).

Future research should apply the capital-theoretic perspective to study the coordination of rules (and associated coordination processes) in the legal system, and particularly the intellectual property regime. It is necessary to examine the impediments to the adaptation of rules at different
levels of the legal order, and to identify where and how coordination processes can break down. We are particularly interested in the sources of what Dopfer and Potts (2008) call “deep coordination failure”. This kind of failure results from poor fit between rules—not only dysfunctional but also missing connections between legal rules.

Another item on the agenda of future research is to draw out the implications of the approach for the co-evolution of law and economic systems. This requires examining the nature of the coupling relationships between the law and the market economy—the peculiarities of the interactions and feedbacks between these two multi-layered systems. We are particularly interested in how a discontinuous change in one system, especially at a lower level (such as a structural break in the norms of legal practitioners), can percolate upwards to generate a new level of structure that is interpolated into the existing legal order and how this can impact the economic system. It would be interesting to investigate how entrepreneurial dynamics in the legal system (e.g. norm innovation, novel litigation strategies) can reverberate on market dynamics, and vice versa.

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