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Product Life Cycle Theory and the Maturation of the Internet

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INTRODUCTION

In recent years, Internet service providers have begun to experiment with a variety of innovative business practices and new forms of network management in an attempt to meet end users' ever increasing demand for more bandwidth and more sophisticated applications. Perhaps most controversially, Comcast began to interfere with the peer-to-peer file sharing application known as BitTorrent by forcing connections associated with BitTorrent to terminate and reconnect. The Federal Communications Commission found Comcast's practices to be unreasonable, only to see the

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courts overturn that decision as exceeding the FCC's statutory authority.[1] Comcast replaced this technique with a protocol-agonistic approach to network management that does not target any particular application and is invoked only during times and in locations that are subject to congestion.[2]

Other network providers are conserving bandwidth by giving higher priority to traffic associated with applications that are particularly sensitive to delay. Among the most sophisticated is the UK's Plusnet, which uses deep packet inspection (DPI) to divide the data stream into seven different levels of priority.[3] Prioritizing traffic in this manner has enabled Plusnet to win numerous industry awards for the quality of its network connections and for customer satisfaction.[4] AT&T's U-verse takes a more limited approach to network management, compensating for its lack of bandwidth by giving priority to a single application: its proprietary video offering.[5] Similarly, Comcast's voice over Internet protocol (VoIP) offering operates over a channel that is completely separate from the public Internet and that does not share bandwidth with other Internet-based applications.[6]

Another development is the emergence of new forms of pricing. For example, Time Warner Cable recently attempted to adopt the practice long followed by digital subscriber line (DSL) providers[7] of offering different tiers of service that provide different levels of bandwidth, only to be forced

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[1] Formal Complaint of Free Press and Public Knowledge Against Comcast Corporation for Secretly Degrading Peer-to-Peer Applications, Memorandum Opinion and Order, 23 F.C.C.R. 13028 (2008) [hereinafter Comcast Order], *petition for review granted sub nom.* Comcast Corp. v. FCC, 600 F.3d 642 (D.C. Cir. 2010). The FCC has issued a notice of inquiry seeking comment on several possible alternative statutory bases for further FCC action. Framework for Broadband Internet Service, Notice of Inquiry, FCC 10-114 (June 17, 2010), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-114A1.pdf.

[2] Letter from Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp., to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n (Sept. 19, 2008), *available at* http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520169715.

[3] Plusnet, Traffic Prioritisation http://www.plus.net/support/broadband/quality_broadband/traffic_prioritisation.shtml (last visited Feb. 23, 2010); *see also Transparency the Key to PlusNet's Success*, STAR (Sheffield, UK), Apr. 9, 2008, http://www.thestar.co.uk/business/Transparency-the-key-to-PlusNet39s.3961139.jp.

[4] Plusnet, Press Centre: Awards, http://www.plus.net/press/awards.shtml (last visited Feb. 23, 2010).

[5] Christopher S. Yoo, *Network Neutrality after* Comcast*: Toward a Case-by-Case Approach to Reasonable Network Management*, *in* NEW DIRECTIONS IN COMMUNICATIONS POLICY 55, 65–66 (Randolph J. May ed., 2009); *see also* AT&T and BellSouth Corp. Application for Transfer of Control, Memorandum Opinion and Order, 22 F.C.C.R. 5662, 5814 (2007) (specifically excluding AT&T's Internet protocol television (IPTV) services from its voluntary network neutrality commitment).

[6] Letter from Kathryn A. Zachem, Vice President, Regulatory Affairs, Comcast Corp., to Dana Shaffer, Chief, Wireline Competition Bureau, & Matthew Berry, Gen. Counsel, Fed. Commc'ns Comm'n at 2 & n.7 (Jan. 30, 2009), *available at* http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520194593 (citing IP Enabled Services, Notice of Proposed Rulemaking, 19 F.C.C.R. 4863, 4873 ¶ 11 & n.42 (2004)).

[7] *See* McGregor McCance, *AT&T Broadband Plans Tiered Service*, RICHMOND (VA) TIMES-DISPATCH, June 16, 2002, at D8 (noting that "[t]iered pricing has long been a staple of DSL providers").

to back down by criticism from the public and from network neutrality advocates.[8] Some backbones and content providers have begun to experiment with paid peering and other interconnection relationships that require payment for traffic that was previously settlement free.[9]

Still other network providers are entering into strategic partnerships with device manufacturers and content providers. Perhaps the most salient recent example is Apple's decision to make the iPhone available exclusively on the AT&T wireless broadband network.[10] Network providers have also given particular search engines preferred treatment, such as the 2001 alliance of SBC—now AT&T—with Yahoo!;[11] Google's $500 million deal to serve as the default search engine on Clearwire's new wireless broadband network;[12] and Google's recent efforts to negotiate a deal to become the default search engine for the Verizon Wireless broadband network, only to be outbid by Microsoft at the eleventh hour.[13]

Proponents of the cluster of policy initiatives that fall under the banner of network neutrality have largely been skeptical of these developments. Some commentators have raised the concern that these types of practices would enable these network providers to act in an anticompetitive manner.[14] Others argue that they threaten innovation in content and applications.[15]

I have discussed these claims at length elsewhere and need not rehearse these arguments here.[16] Instead, this Essay explores another possible ex-

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[8] *See* Christopher S. Yoo, *Network Neutrality, Consumers, and Innovation*, 2008 U. CHI. LEGAL F. 179, 194; Nat Worden, *Time Warner Cable Scraps Plan to Charge by Internet Use*, WALL ST. J., Apr. 17, 2009, at B3.

[9] On paid peering, see Christopher S. Yoo, *Innovations in the Internet's Architecture that Challenge the Status Quo*, 8 J. ON TELECOMM. & HIGH TECH. L. 79, 95–99 (2010). Another example is a service initially known as ESPN 360 and subsequently renamed ESPN3, which is unavailable to Internet subscribers unless their last-mile provider pays a fee to the content provider. *See* Yoo, *supra* note 8, at 238.

[10] Matt Richtel, *In Cingular-Apple Deal, Only a Phone Was Missing*, N.Y. TIMES, Jan. 10, 2007, at C1.

[11] Nick Wingfield, *Yahoo and SBC Will Join Forces to Offer High-Speed Web Access*, WALL ST. J., Nov. 15, 2001, at B8.

[12] Ted Hearn, *Merger Mum on Google; Not Much on Net Neutrality in Clearwire's 300-Page FCC Filing*, MULTICHANNEL NEWS, June 23, 2008, at 34, *available at* http://www.multichannel.com/article/85594-Merger_Mum_on_Google.php.

[13] Amol Sharma et al., *Microsoft Tries to Steal Verizon Deal from Google*, WALL ST. J., Nov. 7, 2008, at B1; Bloomberg News, *Microsoft Taps Dell, Verizon in Search Battle with Google*, SAN JOSE MERCURY NEWS, Jan. 11, 2009, at 7E.

[14] *See, e.g.*, Barbara van Schewick, *Towards an Economic Framework for Network Neutrality Regulation*, 5 J. ON TELECOMM. & HIGH TECH. L. 329, 333 (2007).

[15] *See, e.g.*, LAWRENCE LESSIG, THE FUTURE OF IDEAS 35–37, 39–41, 138–40, 156 (2001); Tim Wu, *Network Neutrality, Broadband Discrimination*, 2 J. ON TELECOMM. & HIGH TECH L. 141, 141–46 (2003).

[16] *See* Christopher S. Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition? A Comment on the End-to-End Debate*, 3 J. ON TELECOMM. & HIGH TECH. L. 23 (2004) [hereinafter Yoo, *Comment on End-to-End*]; Christopher S. Yoo, *Beyond Network Neutrality*, 19 HARV. J.L. & TECH. 1 (2005); Christopher S. Yoo, *Network Neutrality and the Economics of Congestion*, 94 GEO. L.J.

planation for the emergence of these practices that the literature has completely overlooked, specifically the manner in which the nature of competition and innovation change as industries mature. Part I reviews the literature on the theory of the "product life cycle" developed by marketing scholars, which examines how the nature of competition changes as demand growth begins to flatten and the market begins to reach saturation. Part II discusses the scholarship on "dominant designs," to see how standardization affects the nature of innovation. Part III examines the literature on the sociology of technology, which studies how the emergence of a technological paradigm affects scientific progress. Part IV considers the literature on transaction cost economics and complementary assets, which explains how market maturity affects market structure. Part V applies these various theories to the Internet and discusses the critiques and limitations of these theories. This Essay concludes that many of the business practices that are criticized in the current policy debate may well be nothing more than a reflection of the industry's inevitable maturation.

Admittedly, product life cycle theory's inability to predict precisely when and how the nature of competition will shift has limited its usefulness as a tool for *business strategy*. From the standpoint of *regulatory policy*, however, these shortcomings are less problematic. Recognizing that the nature of competition will change at some point cautions against regulatory policies that categorically prohibit the types of practices associated with market maturity even if the theory does not permit policymakers to anticipate exactly when these phase shifts will occur. A case-by-case approach that places the burden of proof on the party challenging the practice would give firms the flexibility they need to experiment with new solutions to respond to changing conditions. Any other approach might well prevent the industry from following its natural evolutionary path.

I. PRODUCT LIFE CYCLE THEORY: THE IMPACT OF DEMAND SATURATION ON THE NATURE OF COMPETITION

The best-known and best-established theory of market maturation is the product life cycle theory pioneered by marketing scholars during the 1950s and 1960s.[17] Although variants of the product life cycle theory ex-

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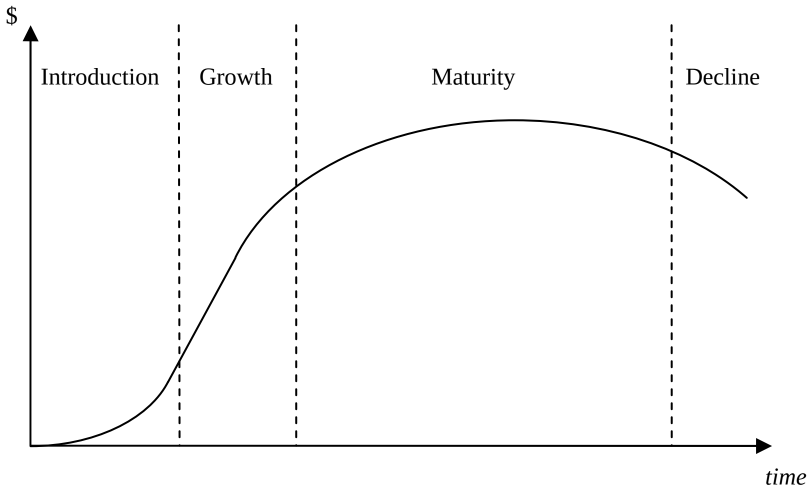
1847 (2006) [hereinafter Yoo, *Economics of Congestion*]; Christopher S. Yoo, *What Can Antitrust Contribute to the Network Neutrality Debate?*, 1 INT'L J. COMM. 493 (2007); Yoo, *supra* note 8; Yoo, *supra* note 5. That said, certain aspects, such as Comcast's failure to disclose its network management practices, are difficult (if not impossible) to justify. *See* Comcast Order, *supra* note 1, at 13058–59 ¶¶ 52–53.

[17] The seminal work on product life cycle theory is Joel Dean's *Pricing Policies for New Products*, HARV. BUS. REV., Nov. 1950, at 45. For other noteworthy early discussions, see Jay W. Forrester, *Industrial Dynamics*, HARV. BUS. REV., July–Aug. 1958, at 37; Arch Patton, *Stretch Your Product's Earning Years*, MGMT. REV., June 1959, at 9; Theodore Levitt, *Exploit the Product Life Cycle*, HARV. BUS. REV., Nov.–Dec. 1965, at 81; William E. Cox, Jr., *Product Life Cycles as Marketing Models*, 40 J. BUS. 375 (1967). The concept is discussed Michael Porter's classic analysis of business strategy. MICHAEL

ist,[18] the predominant version posits that the sales history of a new product will follow an S-shaped curve over time and that the product will pass through the four stages of sales growth depicted in Figure 1.

Figure 1: The Product Life Cycle



During the *introduction* stage, the product's novelty dictates that it will initially achieve only low sales volumes and slow sales growth, during which time the slope of the sales curve will remain relatively flat. If the product is successful, this initial stage gives way to the *growth* stage, during which the upward slope of the sales curve increases, as market penetration accelerates and the product gains acceptance with a broader range of consumers. Over time, market saturation causes the product market to enter the *maturity* stage, during which the sales curve again flattens, and revenue is generated predominantly by sales to existing customers rather than to new customers. Eventually, the product enters the *decline* stage, as the emergence of technologically superior substitutes causes the sales curve to slope

E. PORTER, COMPETITIVE STRATEGY 157–62 (1980). It also figures prominently in leading marketing and strategy textbooks. *See* PHILIP KOTLER & KEVIN LANE KELLER, MARKETING MANAGEMENT 278–88 (13th ed. 2009); ROBERT M. GRANT, CONTEMPORARY STRATEGY ANALYSIS 265–75 (6th ed. 2008).

18 *See, e.g.*, CHESTER R. WASSON, DYNAMIC COMPETITIVE STRATEGY AND PRODUCT LIFE CYCLES 3–10 (1978) (presenting an eight-stage product life cycle).

downward. Empirical research has confirmed that many, if not most, product markets follow the pattern predicted by product life cycle theory.[19]

One key insight of product life cycle theory is that the nature of competition will change as products proceed from one stage to the next.[20] During the introduction stage, firms focus on inducing potential early adopters to try the product. Little focus is placed on price and product quality, in part because early adopters tend to be risk tolerant and price insensitive and in part because low sales volumes prevent firms from standardizing production processes, realizing any significant economies of scale, or obtaining any significant benefits from learning by doing. As the industry transitions from the introductory phase into the growth phase, firms expand beyond early adopters to target the mass market and engage in what is sometimes called "extensive" competition, in which firms race to serve new customers who are entering the market segment.[21]

The most important transition for the purposes of this Essay is the shift from the growth phase to the maturity phase of the life cycle. Extensive competition, which focuses on obtaining new customers, gives way to "intensive" competition, which focuses on delivering more value to customers who are already in the market and on stealing customers already in the market from competitors.[22] Firms compete by improving quality, offering a broader range of product flankers targeted at market segments, and bundling their core product with other services.[23] The flattening of sales growth and the standardization of products also intensifies price competition.[24] Price competition is sharpened further by the growing sophistication of customers, as they become more familiar with the product and how it is

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[19] *See* SAK ONKVISIT & JOHN J. SHAW, PRODUCT LIFE CYCLES AND PRODUCT MANAGEMENT 97–98 (1989) (reviewing the empirical evidence and citing study concluding that more than eighty percent of products investigated followed the classic product life cycle curve); Peter Doyle, *The Realities of the Product Life Cycle*, Q. REV. MKTG., Summer 1976, at 1, 3 (reviewing the empirical literature and concluding that "[s]ales of most, though not all, products broadly follow the PLC pattern"); David R. Rink & John E. Swan, *Product Life Cycle Research: A Literature Review*, 7 J. BUS. RES. 219, 221–22, 238 (1979) (reviewing the empirical literature and concluding that "[t]he weight of evidence suggests that the most common curve is the classical, but it is not the only PLC").

[20] For overviews of changes in the nature of competition during each stage of the product life cycle, see, for example, GRANT, *supra* note 17, at 271; KOTLER & KELLER, *supra* note 17, at 281–88; PORTER, *supra* note 17, at 159–61; Nariman K. Dhalla & Sonia Yuspeh, *Forget the Product Life Cycle Concept!*, HARV. BUS. REV., Jan.–Feb. 1976, at 102, 104.

[21] *See* Richard Gabel, *The Early Competitive Era in Telephone Communications, 1893–1920*, 34 LAW & CONTEMP. PROBS. 340, 345 (1969).

[22] KOTLER & KELLER, *supra* note 17, at 288; Levitt, *supra* note 17, at 89.

[23] GRANT, *supra* note 17, at 271; PORTER, *supra* note 17, at 159.

[24] *See* Dean, *supra* note 17, at 52; Levitt, *supra* note 17, at 83; Patton, *supra* note 17, at 12–13.

sold.[25] The intensification of price competition often causes an industry shakeout and places a higher premium on reducing costs.[26]

The sales history of black-and-white televisions provides an apt illustration of the dynamics of the product life cycle. During the introduction stage, television sets had small screens and significant technical problems. These problems did not prove insuperable, as early adopters were relatively tolerant of poor performance.[27]

As the market for televisions entered the growth stage, sales skyrocketed to the point where retailers struggled to keep sets in stock. The number of manufacturers exploded, numbering as many as sixty within two years and exceeding one hundred within four years of the product's introduction.[28] Manufacturers engaged in a race for the market, both in terms of capturing distribution channels and consumers. The strength of the market demand ensured that margins and profits remained very high. The shift to the mass market and customers' growing sophistication made them more demanding and less tolerant of performance problems.

As the market transitioned into the maturity stage, the slowdown in sales growth caused the nature of competition to change. Price competition intensified, with the number of manufacturers dwindling to thirty-five.[29] Firms became increasingly cost conscious, and instead of trying to capture new customers, they began to offer products that were higher in quality as well as portable televisions and other line extensions that were targeted at niches within the larger market.[30]

Product life cycle theory provides important insights of how the nature of competition changes as markets mature. As consumer adoption approaches saturation, future revenue growth depends not on attracting new customers, but rather on delivering greater value to customers who are already in the market.

II. DOMINANT DESIGN THEORY: THE IMPACT OF PRODUCT STANDARDIZATION ON THE NATURE OF INNOVATION

While marketing-oriented management scholars analyzed how the pattern of sales growth affected the nature of competition, a parallel line of research pioneered by William Abernathy and James Utterback explored how

[25] *See* DAVID A. AAKER, STRATEGIC MARKET MANAGEMENT 66 (8th ed. 2008); George S. Day, *The Product Life Cycle: Analysis and Applications Issues*, J. MKTG., Fall 1981, at 60, 63.

[26] *See* GRANT, *supra* note 17, at 275; Richard G. Hamermesh & Steven B. Silk, *How to Compete in Stagnant Industries*, HARV. BUS. REV., Sept.–Oct. 1979, at 161, 164–65.

[27] Patton, *supra* note 17, at 71–72.

[28] *Id.* at 72.

[29] *Id.* at 76.

[30] *Id.* at 77.

market maturation affects the nature of innovation.[31] Although inspired by product life cycle theory,[32] dominant design theory differs in that the key milestone turns on the standardization of the product rather than sales growth.[33] While Abernathy and Utterback initially argued that innovation proceeds in a series of three distinct phases,[34] they later simplified the analysis into two basic phases, with the division between those two phases marked by the emergence of a dominant design.[35]

According to Abernathy and Utterback, when a technological breakthrough first emerges, considerable uncertainty exists about which product features will appeal most to consumers and about the best technological means for providing those features.[36] During this period, product design remains in a state of flux, as firms experiment with different technological approaches to satisfying consumers' needs. Furthermore, the lack of product standardization offers little reward to specialization in operations and instead gives the advantage to production processes that remain flexible.[37]

At some point, the basic product features and the preferred technological means for delivering those features to consumers coalesce into a dominant design. The product standardization implicit in the emergence of a dominant design heightens price competition in a manner similar to that predicted by product life cycle theory.[38] At the same time, the emergence of a dominant design also brings about a number of changes to the nature of innovation. For example, standardization increases the cost of major product changes while also providing greater rewards to process innovations.[39] What little product innovation that remains will be limited to minor modifi-

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[31] *See* James M. Utterback & William J. Abernathy, *A Dynamic Model of Process and Product Innovation*, 3 OMEGA INT'L J. MGMT. SCI. 639 (1975) [hereinafter Utterback & Abernathy, *Dynamic Model*]; William J. Abernathy & James M. Utterback, *Patterns of Industrial Innovation*, TECH. REV., June/July 1978, at 41 [hereinafter Abernathy & Utterback, *Industrial Innovation*]. For an important antecedent, see Dennis C. Mueller & John E. Tilton, *Research and Development Costs as a Barrier to Entry*, 2 CANADIAN J. ECON. 570 (1969).

[32] Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 643.

[33] WILLIAM J. ABERNATHY ET AL., INDUSTRIAL RENAISSANCE 24 (1983); Kim B. Clark, *Competition, Technical Diversity, and Radical Innovation in the U.S. Auto Industry*, 1 RES. ON TECH. INNOVATION, MGMT. & POL'Y 103, 112–13 (Richard S. Rosenbloom ed., 1983).

[34] Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 641–45.

[35] Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, at 44. For other representative descriptions, see, for example, Rebecca M. Henderson & Kim B. Clark, *Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms*, 35 ADMIN. SCI. Q. 9, 13–14 (1990); Steven Klepper, *Entry, Exit, Growth, and Innovation over the Product Life Cycle*, 86 AM. ECON. REV. 562, 562–63 (1996); Michael L. Tushman & Philip Anderson, *Technological Discontinuities and Organizational Environments*, 31 ADMIN. SCI. Q. 439, 441 (1986).

[36] Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 643.

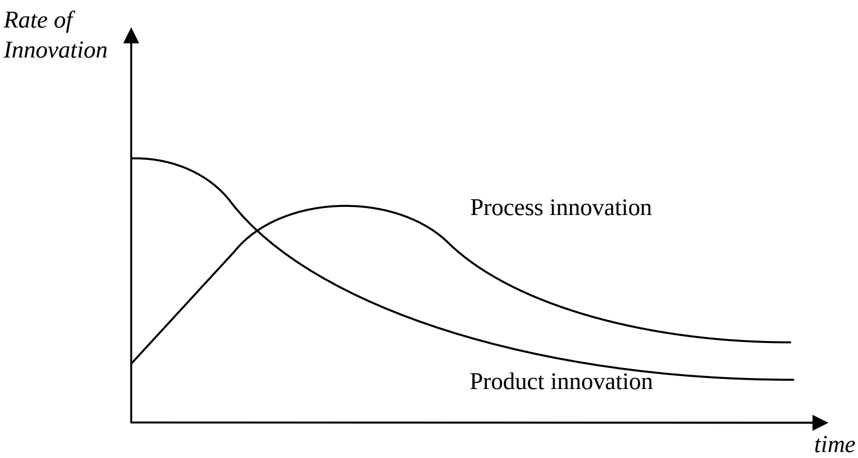
[37] Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, at 44–45.

[38] *Id.* at 44.

[39] Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 644–46.

cations that do not require any major revisions to the product's basic design.[40]

Figure 2: Dominant Design Theory and the Shift from Product to Process Innovation



The reduction in uncertainty associated with the emergence of a dominant design also causes research and development to become more formalized and systematic. As a result, innovation becomes more science-oriented, less driven by trial and error,[41] and tends to become more incremental.[42] The empirical literature largely corroborates the predictions of dominant design theory.[43] As a result, dominant design theory has appeared prominently in many of the leading books on industrial organization and business strategy.[44]

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[40] ABERNATHY ET AL., *supra* note 33, at 24.

[41] William J. Abernathy & Phillip L. Townsend, *Technology, Productivity and Process Change*, 7 TECH. FORECASTING & SOC. CHANGE 379, 391 (1975); Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 646.

[42] Abernathy & Townsend, *supra* note 41, at 391.

[43] For reviews of the empirical literature on dominant designs, see Johann Peter Murmann & Koen Frenken, *Toward a Systematic Framework for Research on Dominant Designs, Technological Innovations, and Industrial Change*, 35 RES. POL'Y 925, 926–30 (2006); Fernando F. Suarez, *Battles for Technological Dominance: An Integrative Framework*, 33 RES. POL'Y 271, 272–73 (2004).

[44] *See, e.g.*, MICHAEL E. PORTER, COMPETITIVE ADVANTAGE 194–95 (1985); OLIVER E. WILLIAMSON, MARKETS AND HIERARCHIES 215–16 (1975).

Again, the history of black-and-white televisions provides a useful case in point. During the industry's initial stages, the product was highly non-standardized, employing both round and rectangular screens in a wide variety of sizes.[45] The fast pace of technological improvements required that manufacturers redesign the product each year, which led them to employ a wide number of models and chassis. But the emergence of a dominant design slowed the pace of product innovation and placed greater emphasis on manufacturing expertise.[46]

Another classic example is the automobile industry.[47] During its earliest years, the Ford Motor Company developed and produced five different engines, which employed anywhere from two to six cylinders. The manufacturing facility was organized flexibly as a job shop, employing trade craftsmen wielding general-purpose tools. Once the Model T emerged as a dominant design, Henry Ford was able to embark on his now legendary deployment of mass production processes that lowered product costs dramatically. These examples illustrate the key role that the emergence of a dominant design plays in shaping the nature of competition, innovation, and industry structure.

III. TECHNOLOGY TRAJECTORIES AND DESIGN HIERARCHIES: THE IMPACT OF THE SOCIOLOGY OF TECHNOLOGY ON TECHNOLOGICAL CHANGE

Although the original proponents of dominant design theory conceded that the movement toward a single technological approach may "stop for long periods, or even reverse,"[48] the overall thrust of their arguments suggested that the movement toward standardization was generally unidirectional and that any deviations from this pattern would be extremely rare.[49] The significant changes to the automobile industry effected by the oil shocks and the entry by Japanese automakers during the 1970s, however, forced these scholars to grapple with the dynamics of industry "dematurity," in which an industry may move away from a dominant design.[50] Even so, they tended to attribute such changes to exogenous forces, such as the

[45] Patton, *supra* note 17, at 72.

[46] *Id.* at 74–75.

[47] Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, at 44.

[48] Utterback & Abernathy, *Dynamic Model*, *supra* note 31, at 645.

[49] Murmann & Frenken, *supra* note 43, at 935 ("In the original formulation of dominant designs, Abernathy and Utterback (1978) suggest that dominant designs emerge once in the evolution of a particular product class."); *see also* James M. Utterback & Fernando F. Suárez, *Innovation, Competition, and Industry Structure*, 22 RES. POL'Y 1, 17 (1993) (noting that while an industry's movement toward a single dominant design "is not necessarily irreversible, the evidence to date indicates that it is highly directional").

[50] William J. Abernathy & Kim B. Clark, *Innovation: Mapping the Winds of Creative Destruction*, 14 RES. POL'Y 3, 18 (1985); *see also* ABERNATHY ET AL., *supra* note 33, at 21, 27; JAMES M. UTTERBACK, MASTERING THE DYNAMICS OF INNOVATION 158–65 (1994).

development of new technologies, shifts in consumer demand, or changes in government policy.[51]

A. Technological Trajectories

Later scholars began to explore a more endogenous theory of how the dynamics of innovation can change based on the sociology of technology. The analytical foundation for this line of research is Thomas Kuhn's seminal work on the history of science, which was initially published in 1962 and republished in subsequent editions in 1970 and 1996. Kuhn argued that each field of technological inquiry tends to be organized around a scientific "paradigm," which he regarded as "the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community."[52] After a paradigm has been established, technological progress takes the form of "normal science," which focuses on solving the puzzles posed by the paradigm rather than challenging the paradigm itself.[53] The establishment of a scientific paradigm plays a key role in promoting scientific progress. As an initial matter, paradigms serve as filters for determining what is relevant.[54] At the same time, the paradigm "provides a map whose details are elucidated by mature scientific research."[55] Indeed, such a map helps organize the discipline around a discrete number of research areas: "By focusing attention upon a small range of relatively esoteric problems, the paradigm forces scientists to investigate some part of nature in a detail and depth that would otherwise be unimaginable."[56]

In other ways, however, paradigms restrict scientific development. Paradigms thus ensure that the field consists of researchers who "have undergone similar educations and professional initiations."[57] In the process, they establish an orthodoxy by determining "legitimate methods, problems, and

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[51] ABERNATHY ET AL., *supra* note 33, at 27–29; Abernathy & Clark, *supra* note 50, at 18.

[52] THOMAS S. KUHN, STRUCTURE OF SCIENTIFIC REVOLUTIONS 175 (3d ed. 1996) [hereinafter KUHN, REVOLUTIONS]. Kuhn has often been criticized for the imprecision with which he used the term paradigm. Margaret Masterman, *The Nature of a Paradigm*, *in* CRITICISM AND THE GROWTH OF KNOWLEDGE 59, 61–66 (Imre Lakatos & Alan Musgrave eds., 1970). Kuhn later admitted that he used the term paradigm too loosely and inconsistently. KUHN, *supra*, at 174–82 (publishing postscript to the second edition originally authored in 1969); Thomas S. Kuhn, *Reflections on My Critics*, *in* CRITICISM AND THE GROWTH OF KNOWLEDGE, *supra*, at 231, 271–72. In his later work, Kuhn attempted to define his terms more narrowly. Thomas S. Kuhn, *Second Thoughts on Paradigms*, *in* THE STRUCTURE OF SCIENTIFIC THEORIES 459 (Frederick Suppe ed., 1977), *reprinted in* THOMAS S. KUHN, THE ESSENTIAL TENSION: SELECTED STUDIES IN SCIENTIFIC TRADITION AND CHANGE 293–319 (1977).

[53] KUHN, REVOLUTIONS, *supra* note 52, at 144.

[54] *See id.* at 15 ("In the absence of a paradigm . . . , all of the facts that could possibly pertain to the development of a given science are likely to seem equally relevant. As a result, early fact-gathering is a far more nearly random activity than the one that subsequent scientific development makes familiar.").

[55] *Id.* at 109.

[56] *Id.* at 24.

[57] *Id.* at 177.

standards of solution."[58] Moreover, during periods of normal science, each paradigm provides a "criterion for choosing problems that . . . can be assumed to have solutions. To a great extent these are the only problems that the community will admit as scientific or encourage its members to undertake."[59] Moreover, paradigms induce a form of tunnel vision that can cause scientists to overlook or disregard data and findings that contradict the paradigm: "[I]ndeed those that will not fit the box are often not seen at all."[60]

Kuhn further posited that every paradigm contains the seeds of its own destruction.[61] Eventually, researchers pursuing normal science make unexpected discoveries that reveal anomalies that the current paradigm cannot explain.[62] At some point, when "an anomaly comes to seem more than just another puzzle of normal science, the transition to crisis and to extraordinary science has begun," during which "formerly standard solutions of solved problems are called in question."[63] These scientific developments are often reinforced by social and economic forces from outside the scientific community that place greater emphasis on these anomalies.[64] This conflict induces a period of "crisis" that is often quite painful for the participants[65] and is often characterized by miscommunication, hostility, and "pronounced professional insecurity."[66] Eventually a new paradigm emerges that can "solve the problems that have led the old one to a crisis,"[67] and the cycle of incremental technological progress—interrupted by intermittent periods of radical technological change—begins again.

A number of technology scholars have built on Kuhn's work to offer more elaborate theories of technological change. Devendra Sahal argued that technological progress results less from the efforts of the "heroic entre-

[58] *Id.* at 48.

[59] *Id.* at 37.

[60] *Id.* at 24; *see also id.* at 5 (noting that "[n]ormal science . . . often suppresses fundamental novelties because they are necessarily subversive of its basic commitments"); *id.* at 37 (noting how the technical community rejects research challenging the paradigm "as metaphysical, as the concern of another discipline, or sometimes as just too problematic to be worth the time"); *id.* at 75 (noting that many new paradigms "had been at least partially anticipated during a period when there was no crisis in the corresponding science; and in the absence of crisis those anticipations had been ignored").

[61] *Id.* at 24 ("[N]ormal science possesses a built-in mechanism that ensures the relaxation of the restrictions that bound research whenever the paradigm from which they derive ceases to function effectively. At that point scientists begin to behave differently and the nature of their research problems changes.").

[62] *See id.* at 5 (noting that eventually "a normal problem, one that ought to be solvable by known rules and procedures, resists the reiterated onslaught of the ablest members of the group within whose competence it falls"); *id.* at 97 (observing the emergence of "recognized anomalies whose characteristic feature is their stubborn refusal to be assimilated to existing paradigms").

[63] *Id.* at 82–83.

[64] *Id.* at 181.

[65] *Id.* at 6, 88, 90–91.

[66] *Id.* at 67–68, 148–50.

[67] *Id.* at 153.

preneur" posited by neoclassical theory and more from the emergence of "technological guideposts" that direct subsequent research along particular "innovation avenues."[68] Sahal appears to have regarded the establishment of a new technological guidepost as an exogenous development, determined either by chance[69] or by the confluence of two lines of technology that were previously thought to be separate.[70]

More or less contemporaneously with Sahal, Giovanni Dosi put forth a more nuanced conception and socially determined theory of how technologies evolve. Specifically, Dosi explicitly invoked Kuhn to argue that industries tend to be guided by "technological paradigms" that frame the way each field identifies the problems worth solving and the most promising technological solutions.[71] Importantly, technological paradigms have both inclusionary and exclusionary effects, steering research away from certain directions and toward others.[72] Like Kuhn, Dosi viewed the decision about whether to establish a technological paradigm as one driven as much by economic forces as by science.[73] Drawing on the work of Nathan Rosenberg, Richard Nelson, and Sidney Winter, Dosi also argued that once established, a technological paradigm guides innovation along a "technological trajectory" which creates a pattern of "normal" problem solving activity.[74]

Philip Anderson and Michael Tushman offered a similar theory that combined the view of "technological change . . . as a sociocultural evolutionary process of variation, selection, and retention" that encompassed both Kuhn's insights and dominant design theory.[75] The process begins with the stochastic emergence of a technological breakthrough that conveys new and decisive cost or quality advantages.[76] These radical advances launch what Anderson and Tushman called an "era of ferment," during

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68 Devendra Sahal, *Technological Guideposts and Innovation Avenues*, 14 RES. POL'Y 61, 71 (1985); *see also* DEVENDRA SAHAL, PATTERNS OF TECHNOLOGICAL INNOVATION 32–36 (1981) (analyzing and providing examples of how technological guideposts shaped the pattern of innovation).

69 Sahal, *supra* note 68, at 78–79; Utterback & Suárez, *supra* note 49, at 6 (noting that under Sahal's theory, technological guideposts emerge largely by chance).

70 SAHAL, *supra* 68, at 36; Sahal, *supra* note 68, at 70.

71 Giovanni Dosi, *Technological Paradigms and Technological Trajectories*, 11 RES. POL'Y 147, 152 (1982).

72 *Id.* at 153.

73 *Id.*

74 *Id.* at 153–54 (citing NATHAN ROSENBERG, PERSPECTIVES ON TECHNOLOGY 110–12 (1976); Richard R. Nelson & Sidney G. Winter, *Dynamic Competition and Technical Progress*, *in* ECONOMIC PROGRESS, PRIVATE VALUES, AND PUBLIC POLICIES: ESSAYS IN HONOR OF WILLIAM FELLNER 57 (Bela Balassa & Richard Nelson eds., 1977); Richard R. Nelson & Sidney G. Winter, *In Search of Useful Theory of Innovation*, 6 RES. POL'Y 36, 56–57 (1977)).

75 Philip Anderson & Michael L. Tushman, *Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change*, 35 ADMN. SCI. Q. 604, 605 (1990). This paper expanded on their earlier work. *See* Tushman & Anderson, *supra* note 35.

76 Anderson & Tushman, *supra* note 75, at 604–05.

which new technologies compete both with each other and with the preceding technological regime.[77] The era of ferment is brought to an end by the adoption of a dominant design, which they equate to Sahal's technological guideposts and Dosi's technological paradigms[78] and which they argue is selected not by technical but by social or political processes.[79] After this point, the industry enters an "era of incremental change," during which "[t]he focus of competition shifts from higher performance to lower cost and to differentiation via minor design variations and strategic positioning tactics."[80] Once entrenched, the dominant design becomes difficult to dislodge, in part because of the realization of scale economies and learning by doing[81] and in part because social structures—such as operating procedures, organizational power structures, and institutional frameworks—tend to reinforce the status quo.[82] Other scholars building on this work have suggested that network economic effects can play a similar role.[83] The result is what some have called "punctuated equilibria," in which long periods of incremental innovation are interrupted by periodic technological discontinuities.[84] Anderson and Tushman reviewed the history of four industries, which they concluded provided empirical support for their theories.[85]

Interestingly, Anderson and Tushman emphasized that not all technological discontinuities create a paradigm shift.[86] Some technological discontinuities are "competence-enhancing" in that they build on existing know-how in ways that are largely consistent with the existing technological paradigm.[87] Because competence-enhancing changes complement the status quo, they are less likely to trigger a new era of ferment or radical changes to industry structure.[88] Other technological discontinuities are "competence-destroying," in that they require new skills, abilities, and

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[77] *Id.* at 610–12.

[78] *Id.* at 613.

[79] *Id.* at 617.

[80] *Id.* at 617–18 (citing PORTER, *supra* note 44).

[81] *Id.* at 614.

[82] *Id.* at 618.

[83] Murmann & Frenken, *supra* note 43, at 935; Steven Klepper, *Industry Life Cycles*, 6 INDUS. & CORP. CHANGE 145, 150 (1997); Suárez, *supra* note 43, at 274.

[84] Tushman & Anderson, *supra* note 35, at 439–41, 444, 450, 455, 460; Ron Adner, *When Are Technologies Disruptive? A Demand-Based View of the Emergence of Competition*, 23 STRATEGIC MGMT. J. 667, 667 (2002); Utterback & Suárez, *supra* note 49, at 7; *see also* Abernathy & Clark, *supra* note 50, at 14 ("[T]he advancement of science is characterized by long periods of regular development, punctuated by periods of revolution.").

[85] Anderson & Tushman, *supra* note 75, at 618–27; *see also* Tushman & Anderson, *supra* note 35, at 450–59 (finding empirical support in the history of the minicomputer, cement, and airline industries).

[86] Anderson and Tushman introduced this concept in Tushman & Anderson, *supra* note 35, at 442–46, 460–62 (citing Abernathy & Clark, *supra* note 50). They extended their analysis in Anderson & Tushman, *supra* note 75, at 609–10, 612–13, 617, 621, 623, 625–26.

[87] Tushman & Anderson, *supra* note 35, at 442.

[88] *Id.* at 445.

knowledge.[89] It is these changes that initiate periods of technological ferment and that disrupt industry structure.[90]

Importantly, Anderson and Tushman underscore that because technological dominance cannot be known in advance, it will be determined largely by intraorganizational political processes.[91] The inherent uncertainty surrounding the likely success of any particular technological advance means that the adoption of an industry standard depends on social, political, and organizational processes more than technical merit.[92] In short, "[t]he passage of an industry from ferment to order is not an engineering issue as much as a sociological one" that involves "a complicated array of organizational and collective forces," including strategic alliances, industry associations, and government agencies.[93] Once an industry standard becomes entrenched, scale economies and learning by doing make it very hard to dislodge.[94]

B. Design Hierarchies

Another line of research examined how technological change is shaped by what Kim Clark called "design hierarchies."[95] Drawing on the work of Nathan Rosenberg, Clark noted that most innovations are not standalone technological developments, but rather part of a web of interdependent technological processes.[96] In addition, not all of the various components that make up these technological processes are of equal importance. Some are central or core, in that they affect all others within the domain. These concepts are placed at the top of the design hierarchy.[97]

The emergence of a particular design hierarchy establishes a technical agenda for a particular product's development that directs further innovation along particular lines.[98] Once the technological agenda has been set, production processes become more focused and specialized.[99] Moreover, the hierarchical nature of the design systems has a tendency to facilitate certain types of innovation and to obstruct others. Specifically, innovations that refine the concepts established by the existing hierarchy (which Clark called movements "down" the design hierarchy), are relatively easy to de-

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89 *Id.* at 442.

90 *Id.* at 444–46, 461–62.

91 *Id.* at 462.

92 Anderson & Tushman, *supra* note 75, at 605–06, 611, 616–17, 627–28.

93 *Id.* at 627–28.

94 *Id.* at 614.

95 Kim B. Clark, *The Interaction of Design Hierarchies and Market Concepts in Technological Evolution*, 14 RES. POL'Y 235, 235 (1985).

96 *Id.* at 237 (citing ROSENBERG, *supra* note 74, at 108–25).

97 *Id.* at 243.

98 *Id.*

99 *Id.* at 247.

ploy, as they reinforce and strengthen existing commitments.[100] Innovations that depart from existing approaches and challenge the core elements that define the design hierarchy (which Clark called movements "up" the design hierarchy) can be more difficult to realize in that they destroy the value of established commitments and competence.[101] Later scholars have taken a more network-based approach that views the importance of a particular concept not in terms of its level of generality within a conceptual hierarchy, but rather the extent of a concept's interconnections with other concepts, with changes to core concepts having a significantly lower probability of success.[102]

Clark refined this analysis and added an institutional dimension to this framework in subsequent work co-authored with Rebecca Henderson.[103] They note that integrating components into a system requires two distinct types of knowledge: "First, it requires component knowledge, or knowledge about each of the core design concepts and the way in which they are implemented in a particular component. Second, it requires architectural knowledge or knowledge about the ways in which the components are integrated and linked together into a coherent whole."[104] These analytical constructs yield the following two-by-two matrix for identifying distinct types of innovation.

Innovations can have dramatically different impacts on competition depending on the extent to which they change each type of knowledge. Obviously, innovations that reinforce current component knowledge and do not require significant changes to current architectural knowledge (which Henderson and Clark called "incremental innovation") are the least disruptive.[105] Conversely, innovations that require significant changes to both component and architectural knowledge ("radical innovation") pose the greatest challenges to established firms, since it is these types of innovations that are most destructive to established firms' existing capabilities.[106]

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[100] *Id.* at 249.

[101] *Id.*

[102] Murmann & Frenken, *supra* note 43, at 940–42; *see also* Michael L. Tushman & Johann Peter Murmann, *Dominant Designs, Technology Cycles, and Organizational Outcomes*, 20 RES. ORG. BEHAV. 231, 249–51 (1998) (noting that "products are composed of hierarchically ordered subsystems that are coupled together by linking mechanisms" in which "core subsystems are either tightly connected to other subsystems or represent a strategic performance bottleneck," while "a peripheral subsystem is one that is only weakly connected to other subsystems"); Michael L. Tushman & Lori Rosenkopf, *Organizational Determinants of Technological Change: Toward a Sociology of Technological Evolution*, 14 RES. ORG. BEHAV. 311, 334 (1992) ("Not all subsystems are of equal importance. Those subsystems with greater linkages to other subsystems are more central to the system than those subsystems that are peripheral.").

[103] Henderson & Clark, *supra* note 35. This article refined ideas initially explored in Abernathy & Clark, *supra* note 50, at 7–13.

[104] Henderson & Clark, *supra* note 35, at 11.

[105] *Id.* at 13.

[106] *Id.*

Figure 3: Interactions in Changes in Component and Architectural Knowledge[107]

		COMPONENT KNOWLEDGE	
		Reinforced	Overturned
ARCHITECTURAL KNOWLEDGE	Unchanged	Incremental Innovation	Modular Innovation
	Changed	Architectural Innovation	Radical Innovation

What is most illuminating is a comparison of the two diagonal boxes of the matrix. Firms accommodate changes to components that do not require changes to the system's architecture ("modular innovation") relatively easily.[108] Interestingly, it is innovations that change the architecture without changing the components ("architectural innovation") that pose the greatest challenges.[109] The emergence of a dominant design tends to stabilize architectural knowledge and leads firms to stop focusing on alternative architectural configurations and instead concentrate on improving the components within the context of the existing configuration.[110] Moreover, once a particular architectural vision becomes dominant, "it tends to become embedded in the practices and procedures of the organization."[111] In particular, "an organization's communication channels will come to embody its architectural knowledge of the linkages between components that are critical to effective design."[112] In addition, the filters that organizations employ to manage the constant barrage of information also come to embody its architectural knowledge.[113] Yet these structures mean that information about changes in the manner in which components relate to one another might become screened out. As Henderson and Clark noted, "organizations facing threats may continue to rely on their old frameworks—or in our terms on their old architectural knowledge—and hence misunderstand the nature of a

[107] *Id.* at 12 fig.1.
[108] *Id.* at 12.
[109] *Id.* at 13.
[110] *Id.* at 14–15.
[111] *Id.* at 15.
[112] *Id.*
[113] *Id.*

threat. They shoehorn the bad news, or the unexpected new information, back into the patterns with which they are familiar."[114] This systematic, institutional commitment to the status quo makes it harder for established firms to recognize when change is necessary and make it more costly for them to retool.[115]

One potential solution to the complexities of design hierarchies is modularity. Clayton Christensen has linked the emergence of modularity to the product life cycle.[116] During the initial stages of a technology, when firms cannot yet meet most consumers' demands for performance, the need to maximize the potential of the existing technology leads firms to experiment with new and untested configurations of components.[117] As a result, firms tend to employ nonstandardized, highly interdependent, and proprietary architectures, rather than modular architectures.[118] This characteristic may be attributed to the fact that standardization would necessarily force firms away from the technological frontier.[119] In addition, product designers need to be free to engage in an unstructured technical dialogue that is not tied to any particular architectural conception.[120] Once the functionality of the available products begins to exceed customers' expectations, the focus of competition shifts away from functionality and toward other considerations, such as speed of service, flexibility, customization, and price, which makes modular architectures better suited to the business environment.[121]

However, even proponents of modularity recognize the theory's limits. For example, certain tasks may be so interdependent that they require a higher degree of coordination than modular architectures allow.[122] Modularization also limits producers' ability to compete on the basis of cost or superior design[123] and tends to create information silos.[124] Because the standards needed to implement a modular approach are typically established by industry organizations or regulatory agencies, adopting a modular architec-

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[114] *Id.* at 17 (citations omitted).

[115] *Id.* at 17–18.

[116] CLAYTON M. CHRISTENSEN, THE INNOVATOR'S DILEMMA 209, 217–18 (1997).

[117] Clayton M. Christensen et al., *Disruption, Disintegration and the Dissipation of Differentiability*, 11 INDUS & CORP. CHANGE 955, 961–62 (2002).

[118] *Id.* at 962.

[119] *Id.*

[120] *Id.*

[121] *Id.* at 964–65; CHRISTENSEN, *supra* note 116, at 214–15, 218–19.

[122] Carliss Y. Baldwin, *Where Do Transactions Come From? Modularity, Transactions and the Boundaries of Firms*, 17 INDUS. & CORP. CHANGE 155, 180–86 (2008); Henry W. Chesbrough & David J. Teece, *When Is Virtual Virtuous?: Organizing for Innovation*, HARV. BUS. REV., Jan.–Feb. 1996, at 65, 70; MICHAEL E. RAYNOR & CLAYTON M. CHRISTENSEN, DELOITTE RESEARCH, INTEGRATE TO INNOVATE 16–19 (2002), *available at* http://www.deloitte.com/assets/Dcom-SouthAfrica/Local%20 Assets/Documents/I2I(1).pdf.

[123] Christensen et al., *supra* note 117, at 977.

[124] Chesbrough & Teece, *supra* note 122, at 65–66.

ture in effect subjects that industry to bureaucratic control.[125] Perhaps most importantly, changes in the technological and economic environment can lead two previously distinct modules to be provided more efficiently by a single integrated system. This occurred, for example, when computers began to integrate functions previously performed by peripheral devices into their primary CPUs[126] and when cable modem and DSL providers began to offer services that consolidated both last-mile and middle-mile functionality.[127] Technological and economic changes can also put pressure on the industry to evolve toward a fundamentally different architecture.[128] The danger is that modularization may inhibit systemic innovation by creating organizational structures and economic pressures that tend to lock the existing interfaces into place.[129]

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Together, these sociological theories have important implications for how technological innovation emerges in mature industries. A number of basic economic factors, such as scale economies, learning by doing, and network economic effects, make transformative change particularly difficult after a technology has coalesced around a particular paradigm. Moreover, paradigms and institutional structures tend to retard radical architectural changes by framing and filtering the way that researchers and organizations perceive new technological developments and information. These problems are likely to be particularly severe for innovations challenging an entrenched design hierarchy, in which the interdependence of multiple subsystems is particularly resistant to change and many researchers and industry players have professional and economic investments in the status quo. These effects can limit the number of dimensions along which firms can compete and can prevent new architectural approaches from emerging.

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125 *See* RAYNOR & CHRISTENSEN, *supra* note 122, at 19 ("Companies that are integrated across modular interfaces suffer from the inefficiencies that seem inevitably to stem from the heavy hand of bureaucratic control.").

126 *See* Transamerica Computer Co. v. IBM Corp., 698 F.2d 1377, 1382–83 (9th Cir. 1983); Cal. Computer Prods., Inc. v. IBM Corp., 613 F.2d 727, 744 (9th Cir. 1979); ILC Peripherals Leading Corp. v. IBM Corp., 448 F. Supp. 228, 231–32 (N.D. Cal. 1978), *aff'd sub nom.*, Memorex Corp. v. IBM Corp., 636 F.2d 1188 (9th Cir. 1980) (per curiam); Telex Corp. v. IBM Corp., 367 F. Supp. 258, 342 (N.D. Okla. 1973), *rev'd on other grounds*, 510 F.2d 894 (10th Cir. 1975).

127 Yoo, *Comment on End-to-End*, *supra* note 16, at 33–34.

128 Baldwin, *supra* note 122, at 180; Chesbrough & Teece, *supra* note 122, at 68; Michael G. Jacobides & Sidney G. Winter, *The Co-Evolution of Capabilities and Transaction Costs: Explaining the Institutional Structure of Production*, 26 STRATEGIC MGMT. J. 395, 405 (2005).

129 Chesbrough & Teece, *supra* note 122, at 65–66; Jacobides & Winter, *supra* note 128, at 404.

IV. COMPLEMENTARY ASSETS AND THE IMPACT OF MARKET MATURATION ON INDUSTRY STRUCTURE

Although the literature on market maturation has focused primarily on the nature of competition and innovation, it also has implications for industry structure. This Part considers the impact of market maturation on horizontal market concentration, the relative benefits of incumbency for innovation, and vertical market structure in turn.

A. Horizontal Market Structure

Market maturation theory has embedded in it a particular vision of how the horizontal market structure of an industry will evolve. For example, product life cycle theory predicts that the prospect of strong sales growth will attract a substantial number of new firms to enter the market during the growth stage. As the market enters the maturity phase, the increase in price competition causes an industry shakeout as market participants merge or exit the market.[130]

Dominant design theory offers similar predictions about the evolution of horizontal market structure. During the initial stage, when product design is in flux, entry by new competitors deconcentrates the market.[131] Throughout this period of flux, newer, smaller firms utilizing flexible, labor-intensive production processes have the advantage over larger firms, which rely on more specialized, high-volume production processes.[132] The internal organization and communications structure of large firms tend to make them less able to adjust to this dynamic environment.

The shift in the nature of competition after a dominant design emerges tips the competitive balance in favor of larger firms. Market adoption of a design paradigm causes research and development to become less entrepreneurial and more science-driven and systematic.[133] At the same time, product standardization limits firms' ability to use product innovation as a source of competitive advantage. Competition increasingly focuses on price, which in turn rewards those firms that can improve their production

[130] GRANT, *supra* note 17, at 271, 272; KOTLER & KELLER, *supra* note 17, at 282–83, 289; PORTER, *supra* note 17, at 161 (citing T.A. STAUDT, D. TAYLOR & D. BOWERSOX, A MANAGERIAL INTRODUCTION TO MARKETING 232–33 (3d ed. 1976); L.T. Wells, Jr., *International Trade: The Product Life Cycle Approach*, *in* THE PRODUCT LIFE CYCLE AND INTERNATIONAL TRADE 3, 10 (Louis T. Wells, Jr., ed., 1972)).

[131] UTTERBACK, *supra* note 50, at 30–31, 33–47; Utterback & Suárez, *supra* note 49, at 1, 5; *see also* Michael Gort & Steven Klepper, *Time Paths in the Diffusion of Product Innovations*, 92 ECON. J. 630, 631 (1982) (providing analytical support for the rapid growth in the number of producers during the early stages following the introduction of a new product); Mueller & Tilton, *supra* note 31, at 574 ("[O]ne usually expects a rush of firms entering a newly formed industry.").

[132] Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, at 42, 44; Mueller & Tilton, *supra* note 31, at 574; Utterback & Suárez, *supra* note 49, at 1, 5.

[133] Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, at 45; Mueller & Tilton, *supra* note 31, at 576–77.

processes and can best realize economies of scale.[134] In addition, as discussed in the next section, larger firms are more likely to possess the complementary assets needed to commercialize the innovation.[135] The resulting emphasis on economies of scale and scope causes an industry shakeout,[136] resulting in what Dosi calls "oligopolistic maturity."[137] A recent survey of the literature on dominant designs finds strong empirical support for the idea that industries will tend to follow this inverted-U pattern of entry and exit.[138] Thus, market maturation theory posits that markets will grow increasingly concentrated as the industry matures regardless of whether one applies the demand-driven approach underlying product life cycle theory or the more technologically oriented approach embodied in dominant design theory.

B. Vertical Market Structure

To date, product life cycle and dominant design theorists have devoted relatively little attention to vertical market structure.[139] The initial work adopted a fairly simplistic approach, positing that the emergence of a dominant design would lead to an increase in vertical integration as firms try to assert greater control over their production processes.[140] Later scholars recognized that firms could accomplish the same objectives through contracts establishing closer relationships with suppliers and distributors instead of through formal vertical integration.[141] Commentators attempting to assess the empirical evidence on vertical integration found it to be mixed on this point.[142]

A line of research initiated by David Teece drew upon the insights of transaction cost economics to offer a more refined theory of vertical market structure. Teece's work sought to solve a persistent riddle of innovation: Why, despite the presence of strong first-mover advantages, do initial inno-

[134] Klepper, *supra* note 35, at 573–74, 580.

[135] David J. Teece, *Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy*, 15 RES. POL'Y 285, 301 (1986).

[136] ABERNATHY ET AL., *supra* note 33, at 131–32; UTTERBACK, *supra* note 50, at 30–31, 33–47, 87–88; Klepper, *supra* note 35, at 562, 564, 574; Utterback & Suárez, *supra* note 49, at 5.

[137] Dosi, *supra* note 71, at 157.

[138] Murmann & Frenken, *supra* note 43, at 931.

[139] Klepper, *supra* note 83, at 152.

[140] UTTERBACK, *supra* note 50, at 90; Utterback & Suárez, *supra* note 49, at 4 (observing that Abernathy & Utterback, *Industrial Innovation*, *supra* note 31, considered vertical integration to be an "inevitable outcome of technological evolution in an industry"). This conclusion contrasts with George Stigler's assertion that maturing industries would exhibit greater vertical disintegration, as the growth of sales volumes made greater specialization possible. *See* George Stigler, *The Division of Labor Is Limited by the Extent of the Market*, 59 J. POL. ECON. 185, 190 (1951).

[141] Utterback & Suárez, *supra* note 49, at 4, 18.

[142] *See* Klepper, *supra* note 83, at 159, 164 (finding that although the auto industry exhibited greater vertical integration as it matured, six other industries did not follow any consistent pattern of vertical integration).

vators so often lose to follow-on competitors?[143] The traditional analysis focused almost exclusively on the presence of patent protection or some other means for ensuring that the initial innovator is able to appropriate the lion's share of the available surplus.[144]

While Teece recognized the importance of appropriability,[145] he pointed out that there was another force at work. Teece observed that innovations generally are not products in and of themselves. Most must be combined with other complementary assets before they can be commercialized.[146] In such cases, the commercial success of an innovation depends not only on the strength of the appropriability regime, but also on the innovator's ability to bargain effectively with the firms that control these key complementary assets.[147]

Complementary assets do not play a significant role during the initial stages of a technology's deployment, since during that time the emphasis is on identifying the optimal product design rather than improving production processes.[148] Moreover, production volumes are so low prior to that time that investments in complementary assets are unlikely to yield significant benefits.[149] The situation changes radically once a dominant design has emerged. At this point, access to complementary assets becomes a critical success factor.[150] An innovator with an ironclad, patent-protected monopoly in a particular technology may have to bargain with another monopolist with exclusive control over a complementary asset that is critical to the technology's commercialization.[151] The owner of the complementary asset may be in a stronger bargaining position than the owner of the new technology, in which case the owner of the complementary asset is more likely to capture the lion's share of the benefits created by the new technology.[152]

The strength of the innovator's bargaining position also depends on whether the complementary assets in question are specialized or generic. If the complementary assets needed to commercialize the innovation are generic, the market is likely to be competitive, and the complementary asset owner will not have to bear the risk of making significant relationship-

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[143] Teece, *supra* note 135, at 285.

[144] *See* Giovanni Dosi, *Sources, Procedures, and Microeconomic Effects of Innovation*, 26 J. ECON. LITERATURE 1120, 1139 (1988) (reviewing the literature). Other bases of appropriability include trade secrets, lead times, costs of duplication, learning-curve effects, and superior sales and service efforts. *Id.*

[145] *See* Teece, *supra* note 135, at 287, 290–92.

[146] *Id.* at 288.

[147] *Id.* at 291–92.

[148] *Id.* at 291.

[149] *Id.*

[150] *Id.*; *see also* Suarez, *supra* note 43, at 282 (noting that complementary asset providers become more important as the market for the dominant design grows).

[151] Teece, *supra* note 135, at 292.

[152] *Id.*

specific investments.[153] Under these circumstances, the innovator should have little trouble negotiating contracts to obtain access to those assets.[154]

Bargaining becomes considerably more complicated when the complementary assets needed to commercialize the innovation are specialized. As an initial matter, owners of specialized complementary assets are more likely to possess market power. If so, they will inherently possess greater bargaining power and will be in a better position to appropriate a greater proportion of the surplus.[155] Moreover, contracting is likely to be especially difficult if a contract requires the owner of the complementary asset to undertake irreversible investments that would be valueless if the relationship between the innovator and the complementary asset owner were to fall apart.[156] When that is the case, the owner of the complementary asset may have to be given some ex ante assurances before undertaking such investments.[157] In addition, the parties are vulnerable to being held up ex post.[158]

The classic solution to this problem is for the innovator to eliminate the need to bargain by vertically integrating and provide all of the complementary assets needed to commercialize the invention itself.[159] That said, vertical integration is expensive—a burden that is likely to weigh particularly heavily on startups.[160] Requiring all firms to obtain access to complementary assets through vertical integration would have the inevitable effect of raising the cost of entry, which in turn would render the market less competitive.[161] Innovators can avoid these costs by foregoing formal vertical integration and instead entering into strategic partnerships with providers of complementary assets.[162] Although the presence of relationship-specific investments may cause risks of opportunistic abuse so severe as to render contractual solutions untenable, under the proper circumstances strategic partnerships can represent an alternative institutional solution that facilitates innovators' commercialization of their products.[163]

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153 *Id.* at 291.

154 *Id.* at 290, 291.

155 *Id.* at 292.

156 *Id.* at 294.

157 *Id.*

158 *Id.* at 290; *see also* Joshua S. Gans & Scott Stern, *The Product Market and the Market for "Ideas": Commercialization Strategies for Technology Entrepreneurs*, 32 RES. POL'Y 333, 334, 339–40 (2003) (describing how firms that control specialized complementary assets necessary to commercialize an innovation can act opportunistically to "hold up" the innovation); Scott Shane, *Technology Regimes and New Firm Formation*, 47 MGMT. SCI. 1173, 1177 (2001) (describing how specialized complementary assets can provide advantages to incumbents).

159 Teece, *supra* note 135, at 290, 295.

160 *Id.* at 293.

161 *Id.* at 302.

162 *Id.* at 293–94.

163 *Id.* at 294.

This perspective suggests that the growing use of strategic partnerships may be nothing more than a natural part of a market's evolution after it matures. Thus, Teece concludes that strategic partnerships "ought to be seen not as attempts to stifle competition, but as mechanisms for lowering entry requirements for innovators."[164]

Other scholars have explored alternative ways to reduce the transaction costs of obtaining access to complementary assets aside from vertical integration and vertical contracting. In particular, these scholars suggest that modularity can create "technologically separable interfaces" that permit inter-firm transactions in places where they otherwise could not occur.[165] Through this process, modularity makes it possible for small, non-vertically integrated firms to specialize in ways that allow them to maximize the benefits of their technical expertise.[166]

As noted earlier, however, modularity facilitates innovation within the context of the existing architecture at the expense of inhibiting innovations that would transform the existing architecture. Many modularity scholars have argued that vertically integrated companies are better at systemic innovations,[167] with integrated solutions being more appropriate when the architecture is interdependent, knitting together component pieces.[168] In addition, the unstructured technical dialogue on which architectural innovation depends may best be undertaken within the boundaries of a firm.[169] Integrated firms may be better positioned to manage the subsequent fluctuations between interdependence and modularity.[170]

V. MARKET MATURATION THEORY'S IMPLICATIONS FOR INTERNET POLICY

Market maturation theory would appear to have clear implications for U.S. Internet policy. The empirical data on the penetration rates of U.S. Internet usage collected by the International Telecommunication Union and

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[164] *Id.* at 302.

[165] ASHISH ARORA ET AL., MARKETS FOR TECHNOLOGY 104, 254–55 (2001); CARLISS BALDWIN & KIM CLARK, DESIGN RULES: THE POWER OF MODULARITY 372, 383 (2000); Baldwin, *supra* note 122, at 155, 174–75, 179, 187; Jacobides & Winter, *supra* note 128, at 402.

[166] ARORA ET AL., *supra* note 165, at 254–55; Christensen et al., *supra* note 117, at 964–65, 985; Jacobides & Winter, *supra* note 128, at 403–04; *see also* Klepper, *supra* note 83, at 169–74 (providing empirical support for such specialized firms in maturity).

[167] Chesbrough & Teece, *supra* note 122, at 65.

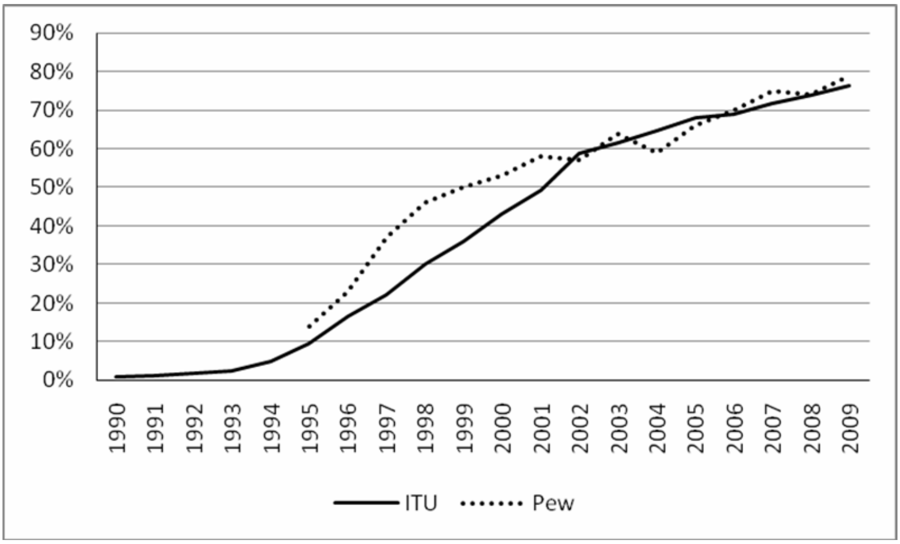
[168] *See* RAYNOR & CHRISTENSEN, *supra* note 122, at 16–19.

[169] Christensen et al., *supra* note 117, at 962–63.

[170] H.W. Chesbrough & K. Kusunoki, *The Modularity Trap: Innovation, Technology Phase Shifts and the Resulting Limits of Virtual Organizations*, *in* MANAGING INDUSTRIAL KNOWLEDGE 202, 227 (Ikujiro Nonaka & David J. Teece eds., 2001); Christensen et al., *supra* note 117, at 975.

by the Pew Research Center indicate that penetration stands at between 76% and 79%.[171]

Figure 4: Penetration of U.S. Internet Usage[172]



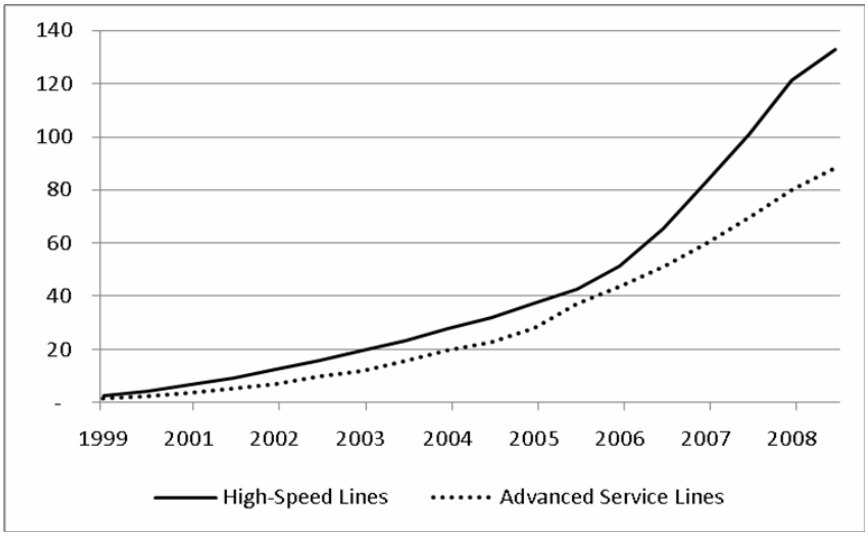
Measured solely in terms of broadband connections, U.S. subscribership has risen rapidly over the past decade. But the growth rate began to taper off in June 2008, as the growth curve passed the inflection point, suggesting that the market may be approaching saturation and may be starting to enter its mature phase.[173]

[171] Int'l Telecomm. Union, United States ICT Statistics (2009), http://www.itu.int/ITU-D/icteye/DisplayCountry.aspx?countryId=244 (76.24 users per 100 inhabitants in 2008); PEW INTERNET & AMERICAN LIFE PROJECT, TREND DATA: USAGE OVER TIME (2009), http://www.pewinternet.org/Trend-Data/Usage-Over-Time.aspx (select "Usage Over Time" spreadsheet) (indicating 74% internet adoption in December 2008).

[172] Int'l Telecomm. Union, ICT Statistics Database (2008), http://www.itu.int/ITU-D/ICTEYE/Indicators/Indicators.aspx (select year in dropdown box and click "4. Internet indicators"); PEW INTERNET & AMERICAN LIFE PROJECT, *supra* note 171.

[173] The FCC this year issued broadband adoption data for December 2008. Unfortunately, because of a change in methodology, these data are not comparable to preceding data. FCC, HIGH-SPEED SERVICES FOR INTERNET ACCESS: STATUS AS OF DECEMBER 31, 2008, at 3–4 (Feb. 2010), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296239A1.pdf.

Figure 5: U.S. Broadband Subscribers (millions)[174]



On a technological level, the Internet initially served as an experimental testbed that allowed researchers to try out a wide variety of network technologies.[175] Moreover, the fact that the Internet was initially sponsored by the Defense Department meant that the architecture placed little emphasis on efficiency or on how costs were allocated.[176] The commercialization of the Internet and its emergence as a mass market phenomenon is naturally leading network providers to deploy increasingly specialized equipment and to place greater emphasis on cost, efficiency, and accountability.

Thus, as the market matures, policymakers should expect firms to shift from extensive to intensive competition and to focus on reducing costs and customizing offerings to deliver greater value to existing customers through differentiation and bundling of services, as reflected by last-mile providers' growing interest in monetizing video streams. Indeed, market maturation theory reminds us that product differentiation can represent an important

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[174] FCC, HIGH-SPEED ACCESS FOR INTERNET ACCESS: STATUS AS OF JUNE 30, 2008 tbl.1 (July 2009), *available at* http://www.fcc.gov/Bureaus/Common_Carrier/Reports/FCC-State_Link/IAD/hspd0608_tables.xls.

[175] Juan D. Rogers, *Internetworking and the Politics of Science: NSFNET in Internet History*, 14 INFO. SOC'Y 213, 215 (1998).

[176] David D. Clark, *The Design Philosophy of the DARPA Internet Protocols*, 18 ACM SIGCOMM COMPUTER COMMC'NS REV., Aug. 1988, at 106, 107, 110.

source of competitive rivalry.[177] The theory also suggests that policymakers should be tolerant of new institutional relationships, particularly the growing use of more strategic partnerships. The Internet is characterized by precisely the type of relationship-specific investments that counsel in favor of such strategic partnerships.[178] Finally, the impediments to architectural innovation that surround industries characterized by elaborate and complex design hierarchies suggests that policymakers should be concerned that industry players will engage in too little architectural innovation and experimentation rather than too much. The growing consensus in the engineering literature is that the Internet is in need of significant architectural change, but that the network seems incapable of evolving out of its current architecture.[179]

Before condemning particular deviations from the current architecture as harmful to competition and innovation, one should bear in mind that the general concern raised by the literature on network economic effects is that networks to can be too slow to adopt new technologies where the presence of a large installed base causes the network to remain locked into a standard long after it has become obsolete.[180] One should also bear in mind that experimentation and competition over standards are generally regarded as signs of innovative health[181] and that "divided technical leadership," in which firms operating in adjacent markets with similar technical and marketing capabilities attempt to seize control over key platform elements, can represent an important source of competition during Kuhnian eras of normal science.[182] Consequently, regulatory intervention that locks the interfaces between the various components of the design hierarchy into place might actually serve to dampen rivalry rather than enhance it.

Market maturation theory is subject to a number of limitations. Despite the popularity of the various market maturation theories and the attention that management scholars have focused on them, these theories to date have been somewhat disappointing as a guide for managerial decisionmaking. As an initial matter, critics have raised questions about the market ma-

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[177] Ron Adner & Daniel Levinthal, *Demand Heterogeneity and Technology Evolution: Implications for Product and Process Innovation*, 47 MGMT. SCI. 611, 623 (2001).

[178] Christopher S. Yoo, *Vertical Integration and Media Regulation in the New Economy*, 19 YALE J. ON REG. 171, 260–65 (2002).

[179] *See* Paul Laskowski & John Chuang, A Leap of Faith? From Large-Scale Testbed to the Global Internet 2 (2009) (unpublished manuscript, presented at the 37th Annual Telecomm. Pol'y Res. Conf.), *available* at http://www.tprcweb.com/images/stories/papers/Laskowski_2009.pdf (collecting sources).

[180] Yoo, *supra* note 8, at 244.

[181] Shane Greenstein, *Glimmers and Signs of Innovative Health in the Commercial Internet: A Reflective Essay*, 8 J. ON TELECOMM. & HIGH TECH. L. 25, 42–55 (2010).

[182] Timothy F. Bresnahan, *New Modes of Competition: Implications for the Future Structure of the Computer Industry*, *in* COMPETITION, INNOVATION AND THE MICROSOFT MONOPOLY: ANTITRUST IN THE DIGITAL MARKETPLACE 155, 166–69, 172–73, 199–203 (Jeffrey A. Eisenach & Thomas M. Lenard eds., 1999).

turation theory's generality. For example, although reviews of the empirical literature on the product life cycle have concluded that most industries conform to the pattern depicted in Figure 1, critics recognize that many studies reflect a wide variety of other patterns.[183] Similarly, many empirical tests have failed to bear out the dropoff in innovation or the shift from product to process innovation predicted by dominant design theory.[184]

The somewhat inconclusive state of the empirical record is partly attributable to the considerable confusion about the proper unit of analysis. For example, under product life cycle theory, it is unclear whether products should be aggregated at the level of the brand (e.g., Miller), product form (e.g., light beer), or product (e.g., beer).[185] With respect to dominant design theories, studies have struggled to determine what constitutes a dominant design.[186] In addition, studies have varied the unit of analysis, with some analyzing technologies at the product level and others analyzing technologies at the subsystem level.[187] The difficulty in identifying the key turning points has led some scholars to criticize market maturation as only knowable in retrospect,[188] which greatly limits its usefulness to business strategists.

Dominant design theory also assumes that some degree of technological product differentiation is possible. Otherwise, products will standardize quickly without passing through any extended period of uncertainty. Furthermore, in assuming that products will standardize and firms will compete increasingly on the basis of price, the dynamics posited by market maturation theory also implicitly assume that consumer preferences are homogeneous.[189] Heterogeneity of consumer preferences can prevent a dominant

[183] *See* KOTLER & KELLER, *supra* note 17, at 278–79; Rink & Swan, *supra* note 19, at 221–22; Gerald J. Tellis & C. Merle Crawford, *An Evolutionary Approach to Product Growth Theory*, J. MARKETING, Fall 1981, at 125, 126.

[184] For studies finding continued innovation after maturity, see Adner & Levinthal, *supra* note 177, at 623; Clayton M. Christensen, *Exploring the Limits of the Technology S-Curve*, 1 PRODUCTION & OPERATIONS MGMT. 334, 338–41 (1992); Rebecca Henderson, *Of Life Cycles Real and Imaginary: The Unexpectedly Long Old Age of Optical Lithography*, 24 RES. POL'Y 631, 634 (1995); Klepper, *supra* note 83, at 158–60, 167–68. For studies failing to find a shift from product to process innovation after maturity, see Adner & Levinthal, *supra* note 177, at 623; C. De Bresson & J. Townsend, *Multivariate Models for Innovation—Looking at the Abernathy-Utterback Model with Other Data*, 9 OMEGA INT'L J. MGMT. SCI. 429, 435 (1981); Klepper, *supra* note 83, at 175.

[185] Day, *supra* note 25, at 61; Dhalla & Yuspeh, *supra* note 20, at 103–04, 105; Rink & Swan, *supra* note 19, at 225–27.

[186] Murmann & Frenken, *supra* note 43, at 933.

[187] *Id.* at 933–34.

[188] Tushman & Anderson, *supra* note 35, at 443; *see also* Carliss Baldwin et al., *How User Innovations Become Commercial Products: A Theoretical Investigation and Case Study*, 35 RES. POL'Y 1291, 1293 (2006) (noting criticism of the dominant design theory for its ambiguity and its dependence on post hoc appraisals); Dhalla & Yuspeh, *supra* note 20, at 102–08 (criticizing the utility of product life cycle theory as a predictive tool).

[189] PORTER, *supra* note 44, at 196.

design from ever emerging.[190] Moreover, demand heterogeneity may lead firms to continue to make product improvements in maturity.[191] In addition, the market structure predicted by market maturation theory depends on the presence of significant economies of scale, since the continued viability of custom manufacturing would permit small firms to continue to survive.[192]

Most importantly, market maturation theory has struggled to find a theory of market renewal. As Theodore Levitt demonstrated, firms can often find new uses for a product that can revitalize and restart the product life cycle.[193] However, product life cycle theory provides no basis for analyzing when that might occur. Similarly, Abernathy and Utterback's initial exposition of dominant design theory presumed that a dominant design would arise only once in the history of any industry.[194] Since that time, they recognized that industries may go through different cycles.[195]

The problems associated with employing market maturation theory as a guide for *business strategy* do not necessarily undercut its usefulness as a guide for *regulatory policy*. Unlike business managers, policymakers need not determine in advance the precise moments when the nature of competition and innovation will change or which technology will emerge as dominant. Rather than trying to manage the details of these technological transitions, policymakers can simply focus on creating regulatory structures that are flexible enough to allow the industry to evolve as it matures and to give firms the room to experiment with new solutions to whatever changes in the business environment may arise, as would be accomplished by a case-by-case approach that places the burden of proof on the party challenging the practice in question.[196] More aggressive intervention would have the unfortunate effect of preventing ambiguous practices from going forward and runs the risk of biasing technological choices or creating barriers

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[190] Anderson & Tushman, *supra* note 75, at 628.

[191] Adner & Levinthal, *supra* note 177, at 623, 625.

[192] *See* PORTER, *supra* note 44, at 195–96; De Bresson & Townsend, *supra* note 184, at 435.

[193] Levitt, *supra* note 17, at 87–93.

[194] *See* Murmann & Frenken, *supra* note 43, at 935.

[195] ABERNATHY ET AL., *supra* note 33, at 27–29; UTTERBACK, *supra* note 50, at 158–65; Philip Anderson & Michael L. Tushman, *Technological Discontinuities and Dominant Design: A Cyclical Model of Technological Change*, 35 ADMIN. SCI. Q. 604, 605 (1990); Kim B. Clark, *Competition, Technical Diversity, and Radical Innovation in the U.S. Auto Industry*, 1 RES. ON TECH. INNOVATION MGMT. & POL'Y 103, 105 (Richard S. Rosenbloom ed., 1983).

[196] For my previous work advocating an ex post, case-by-case approach, see Yoo, *Comment on End-to-End*, *supra* note 16, at 43–46, 58–59; Yoo, *Beyond Network Neutrality*, *supra* note 16, at 7–8, 24, 75–76; Yoo, *Economics of Congestion*, *supra* note 16, at 1854–55, 1900, 1908; Yoo, *supra* note 8, at 186–87, 212, 227, 238, 246–47, 257, 261; Yoo, *supra* note 5. The FCC's recent *Comcast* order embraced such a case-by-case approach. Comcast Order, *supra* note 1, at 13044–50 ¶¶ 28–40. In a recent speech, FCC Chairman Julius Genachowski expressed his support for a case-by-case approach. Julius Genachowski, Chairman, Fed. Commc'ns Comm'n, Preserving a Free and Open Internet: A Platform for Innovation, Opportunity, and Prosperity, Prepared Remarks at the Brookings Institution (Sept. 21, 2009), *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-293568A1.pdf.

to innovation by increasing costs or uncertainty.[197] A more measured, case-by-case approach that places the burden of proof on the party challenging the practice in question would seem to strike a better balance between permitting business practices to evolve with the changing conditions while also providing a remedy for any anticompetitive harms that may emerge.

[197] ORGANISATION FOR ECON. CO-OPERATION AND DEV., REGULATORY REFORM AND INNOVATION 12 (1996), *available at* http://www.oecd.org/dataoecd/23/61/2102514.pdf; Utterback & Abernathy, *supra* note 31, at 46.