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ANTITRUST AFTER THE COMING WAVE

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A coming wave of general-purpose technologies, including artificial intelligence ("AI"), robotics, quantum computing, synthetic biology, energy expansion, and nanotechnology, is likely to fundamentally reshape the economy and erode the assumptions on which the antitrust order is predicated. First, AI-driven systems will vastly improve firms' ability to detect (and even program) consumer preferences without the benefit of price signals, which will undermine the traditional information-producing benefit of competitive markets. Similarly, these systems will be able to determine comparative producer efficiency without relying on competitive signals. Second, AI systems will invert the salient characteristics of human managers, whose intentions are opaque but actions discernible. An AI's "intentions"—its programmed objective functions—are easily discernible, but its actions or processing steps are a black box. Third, the near-infinite scalability of the technologies in the coming wave will likely result in extreme market concentration, with a few megafirms dominating. Finally, AI and related productive systems will be able to avoid traditional prohibitions on both collusion and exclusion, with the consequence that antitrust law's core prohibitions will become ineffective. The cumulative effect of these tendencies of the coming wave likely will be to retire the economic order based on mandated competition. As in past cases of natural monopoly, some form of regulation will probably replace antitrust, but the forms of regulation are likely to look quite different. Rather than attempting to set a regulated firm's prices by determining its costs and revenues, the regulatory future is more likely to involve direct regulation of an AI's objective functions, for example by directing the AI to maximize social welfare and allocate the surplus created among different stakeholders of the firm.

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INTRODUCTION

A coming technological wave, consisting of a variety of overlapping and mutually reinforcing general-purpose technologies, including artificial intelligence ("AI"), robotics, quantum computing, synthetic biology, energy expansion, and nanotechnology,[1] will fundamentally

[1] *See generally* MUSTAFA SULEYMAN & MICHAEL BHASKAR, THE COMING WAVE: TECHNOLOGY, POWER, AND THE TWENTY-FIRST CENTURY'S GREATEST DILEMMA 92–102 (2023)

alter human existence at a scale not experienced since . . . since when? Fire? The wheel? The Renaissance? Gutenberg's printing press? The Industrial Revolution? The advent of computers or the internet? Ever? That we will not be able to answer this question until the wave has swamped us points to the inherently speculative nature of prognosticating its effects—for better or worse—on any discrete area of human experience or endeavor. Law, of course, is not exempt. Nonetheless, law is about planning,[2] big and small, and planning requires prognostication. So, sitting on the edge of the coming wave, legal planners cannot help but ask about what it might mean for law and start making even vague and contingent plans for different paths the revolution might take.

This Article is about planning for the future of antitrust—if antitrust has a long-term future at all. It may be that it doesn't, and this Article will consider the possibility of its complete obsolescence. But it will also consider the possibility that, although the coming revolution may fundamentally burn away the assumptions on which antitrust law is built, a phoenix form of antitrust may rise and take hold as a functioning instrument in the new technological order. The point is not to suggest the inevitability of any particular path or outcome, or even to suggest any current steps to be taken in anticipation of the coming wave, but rather to look "through a glass, darkly,"[3] at what the coming wave may do to the assumptions and operations undergirding the market-based system of economic production and allocation and the legal rules created to govern it. Even if the full effects of the coming wave are not realized for years or decades, it is none too early to begin planning for the dramatic economic changes that are already in progress and will only become more pronounced with the passage of time.

The core point is this: Antitrust law is premised on four assumptions or pillars that will likely buckle in the coming wave. They are: (1) competitive markets provide the best measure of information about consumer preference and producer efficiency; (2) competitive markets create incentive structures necessary to the maximization of human welfare; (3) consolidation of economic power in very large units of production or distribution is not inevitable; and (4) legal principles and their enforcement can meaningfully police anticompetitive conduct. Each of these assumptions is necessary to the justification and operation of the

(arguing that AI and synthetic biology will transform human experience in the coming decades, and that they will be supplemented by dramatic enhancements in robotics, quantum computing, energy enhancement, and, later, nanotechnology).

[2] *See generally* Scott J. Shapiro, Legality (2011) (arguing that planning is an essential attribute of law).

[3] 1 *Corinthians* 13:12 (King James).

antitrust order as currently specified, and thus the relaxation of any of them threatens to bring down that order. All four assumptions are vulnerable to the coming technological wave. The interactive collapse of these four pillars strongly suggests the collapse of the entire structure of antitrust as we know it on a time horizon measured in years or decades.

In brief as to each of the pillars: First, the information-producing or discovery function of competitive markets will become subject to the challenge that AI and robotic systems may become far more adept at anticipating and fulfilling human wants and needs than market price signals. This will occur not only because AI and robotics systems will be able to forecast changing demand far more efficiently than markets, but also because AI systems augmented by synthetic biology and other technologies will restructure, reshape, and indeed begin to program the attributes of human demand. At the limit, consumer demand will no longer be exogenous to the system of production and distribution; it will be created by that system.[4] Second, the competition paradigm on which antitrust law is based assumes that individual motivation is too multifaceted, ambiguous, unknowable, and variable to regulate directly, but that a competitive spur serves to direct human incentives toward beneficial outcomes by regulating competitive behavior. What changes with AI is that operational commands and objective functions must be explicitly stated and coded, but processing steps are a black box. Thus, with humans, motivations are opaque, but processing steps tend to be clear. With AI and robots, motivations—directions—are clear, and processing steps are opaque. The prospect that key productive assets will have clearly knowable incentives (or goals, or marching orders, or objective functions) but unknowable processes will flip the entire antitrust paradigm on its head.[5] Third, antitrust's competition paradigm assumes that it is possible for an economy to operate with multiple independent and rivalrous units. Already, the digital revolution and its associated scale economies and network effects have shifted scale dramatically toward the large and monopolistic. AI, robotic production, and the continuing shift in economic value from atoms to bits will likely turbocharge these effects, with an inevitable and perhaps unstoppable tendency toward monopolistic megafirms.[6] Finally, antitrust's technologies for controlling anticompetitive behavior will run into a wall as far more powerful technologies for engaging in anticompetitive behavior emerge. The controlling and engaging technologies are not likely to develop with symmetrical strength. In the arms race between

4 *See infra* Section III.A.
5 *See infra* Section III.B.
6 *See infra* Section III.C.

enforcers and monopolists, technological trends give the monopolists a decided upper hand.[7]

Planning for the response to these coming trends when their occurrence, shape, and timing remain highly speculative may seem unduly ambitious, but it is at least possible to begin grouping the potential responses into broad categories. A first category of response would involve efforts to maintain a competitive market system and the antitrust laws that protect it despite the increasing pressures of the coming wave. That is the course likely to be followed for the immediate future and, for at least some economic sectors, for longer. A second category of response would involve conceding that large-scale productive organization will become inevitable, but nonetheless attempting to maintain some degree of economic rivalry by moving the locus of competition from among firms to within firms. But for many of the same reasons that the coming wave will tend to diminish or eliminate inter-firm competition, it will also make it very difficult to mandate intra-firm competition. That leaves a third possibility, and one with a long historical pedigree—declaring the post-wave megafirms to be natural monopolies and subjecting them to comprehensive public utility-style regulation. Although some comprehensive regulatory scheme seems to be the most likely eventual outcome, the existing models of public utility regulation, particularly price controls based on costs and revenues, are poor candidates for controlling the power of the post-wave monopolists. Instead, post-wave regulation will likely employ the power of AI itself to mandate that an AI's objective functions—its programmed orders—be crafted to achieve socially desirable outcomes.

To flesh out these arguments, this Article takes the following shape: Part I frames the issues by showing that four pillars—information, incentives, scale and scope, and conduct control—uphold the antitrust order. The first two pillars go to the justifications for relying on market competition rather than other forms of economic organization. The second two go to the ability of antitrust institutions to instill and police market competition. Part II briefly describes the technological forces that, together, constitute a "coming wave"[8] that will radically alter the assumptions on which the existing economic system is predicated. Part III argues that each of the four pillars of the antitrust order will buckle in the coming wave. The information and incentives justifications for market competition will buckle as new technological systems allow for direct access to and molding of consumer preferences and direct programming of productive systems. The scale and scope and conduct

[7] *See infra* Section III.D.

[8] *See* Suleyman & Bhaskar, *supra* note 1.

control pillars will buckle as the near-infinite scalability of post-wave technologies causes business consolidation into megafirms, and the antitrust system loses its ability to prevent collusion or exclusion. When the pillars do buckle, it is hard to see how the antitrust enterprise can carry on in anything like the form it presently takes and has taken since the beginning. Finally, Part IV considers the three potential responses described in the previous paragraph. It argues that neither trying to mandate competition nor replicating competition within the megafirms is likely to be a successful long-term strategy after the collapse of the four pillars. Rather, any effective solutions will require moving beyond competition as the organizing economic concept and considering a different regulatory approach to engineering production and distribution to maximize human welfare, distribute power, and achieve equitable outcomes—an approach that harnesses the power of the coming wave technologies as both subject and means of regulation.

I
The Four Pillars of Antitrust as Market Competition

Whatever its particular objectives, which remain disputed,[9] the antitrust system is premised on a commitment to competitive markets as the central organizing principle of the economy.[10] The Supreme Court has described the Sherman Act as reflecting "a legislative judgment that ultimately competition will produce not only lower prices, but also better goods and services. 'The heart of our national economic policy long has been faith in the value of competition.'"[11] Markets and competition are intertwined in this narrative. Markets are preferred to other modes of economic organization, and competition is the force necessary to make markets work to the public benefit. Hence antitrust, which mandates market competition.

Like any legal or economic system, antitrust as market competition has an underlying conceptual structure consisting of purposes and operations, each of which can be considered a pillar of the antitrust order. The first two pillars—information and incentives—concern the justifications for committing our system of production and distribution

[9] *See, e.g.*, Mark Glick, Gabriel A. Lozada & Darren Bush, *Why Economists Should Support Populist Antitrust Goals*, 2023 Utah L. Rev. 769, 770–71 (summarizing some potential goals of antitrust law, including improving consumer welfare, dispersing economic and political power, protecting small business, alleviating inequality, protecting labor, protecting macroeconomic growth and stability, and encouraging sustainability).

[10] *See generally* Daniel A. Crane, *The Radical Challenge to the Antitrust Order*, 59 Wake Forest L. Rev. 399 (2024).

[11] Nat'l Soc'y of Pro. Eng'rs v. United States, 435 U.S. 679, 695 (1978).

to competitive markets as opposed to some other form of economic organization, like central planning or monopoly franchises. In short, competitive markets are thought to have significant performance advantages over alternative economic modalities because they are uniquely capable of generating necessary information about consumer demand and producer efficiency and because they give producers incentives to maximize consumer wellbeing.[12]

The second two pillars—structure and conduct—relate to the legal technologies available to the state to ensure that markets behave competitively. Depending on one's point of view, structure and conduct are either alternative focal points for antitrust policy or market attributes that can be tackled simultaneously. For example, the Structure-Conduct-Performance or Harvard School that dominated United States antitrust policy from the 1950s–70s argued that a market's structure (i.e., whether it was monopolistic, concentrated, or competitive) determined the conduct of the firms in the market, which in turn determined the market's performance (i.e., prices, quality, and innovation).[13] Since conduct was difficult to police, the structuralists argued that antitrust policy should be focused on preventing concentrated market structures through such techniques as aggressive merger policy and no-fault monopolization.[14] By contrast, the Chicago School that largely replaced the structuralists in influence beginning in the 1970s argued that concentrated market structures did not necessarily lead to subpar market performance, and they expressed greater confidence in the state's capacity to police anticompetitive behavior.[15] Contemporary antitrust policy reflects the view that both structure and conduct can and should be policed in equal measure.[16] Anticompetitive mergers or joint ventures are blocked, and anticompetitive behaviors like cartels and exclusionary contracts are prohibited.[17]

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12 *See infra* Sections I.A and I.B.

13 *See* The Making of Competition Policy: Legal and Economic Sources 318–20 (Daniel A. Crane & Herbert Hovenkamp eds., 2013).

14 *See id.*

15 *Compare* Daniel A. Crane, *Chicago, Post-Chicago, and Neo-Chicago*, 76 U. Chi. L. Rev. 1911, 1916–18 (2009) (book review) (discussing the view of leading Chicago School scholars that oligopolistic markets could be adequately policed through prohibitions on collusive behavior), *and* Richard A. Posner, *Oligopoly and the Antitrust Laws: A Suggested Approach*, 21 Stan. L. Rev. 1562, 1575 (1969) (arguing that both explicit and tacit collusion can be policed under the antitrust laws), *with* Donald F. Turner, *The Definition of Agreement Under the Sherman Act: Conscious Parallelism and Refusals to Deal*, 75 Harv. L. Rev. 655, 658, 663 (1962) (proposing a narrow definition of agreement under Section 1 of the Sherman Act).

16 *See generally* Daniel A. Crane, Antitrust (2d ed. 2024).

17 *See id.*

Putting it all together, the antitrust order rests on the dual beliefs that competitive markets outperform other systems because they are better at solving information and incentive problems, and that the law can enforce competition by policing both structure and conduct. Now, the details.

A. Information

Why do competitive markets outperform centrally planned economies? The first part of the answer, famously given by Friedrich von Hayek in 1945, is that markets solve information problems.[18] As Hayek argued, if a central planner "possess[ed] all the relevant information," "start[ed] out from a given system of preferences," and "command[ed] complete knowledge of available means," then organizing an economy would become purely a question of logic.[19] But the omniscient central planner doesn't exist: "the 'data' from which the economic calculus starts are never for the whole society 'given' to a single mind which could work out the implications, and can never be so given."[20] Since only the individual members of society know the relative importance they attach to the allocation of resources, Hayek argued, it is impossible for a central planner to make accurate decisions that maximize social welfare.[21] For Hayek, the alternatives to central planning—"direction of the whole economic system according to one unified plan"—is either "delegation of planning to organized industries, or, in other words, monopoly," or competition, which entails "decentralized planning by many separate persons."[22] Since "few [people] like [monopoly] when they see it," a competitively oriented market economy provides the best means of generating the information necessary to determine how resources should be allocated.[23]

Competitive markets generate price signals that provide information about individual utility functions.[24] The demand curves that undergird the essential building blocks of antitrust enforcement, such

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18 *See* F.A. Hayek, *The Use of Knowledge in Society*, 35 Am. Econ. Rev. 519, 521, 524, 526 (1945).

19 *Id.* at 519.

20 *Id.*

21 *Id.* at 519–20.

22 *Id.* at 521.

23 *Id.*

24 *See* Armen A. Alchian & William R. Allen, Exchange and Production Theory in Use ch. 5 (1964) (discussing how price signals provide information about supply and demand); *see also* Oliver E. Williamson, *The Evolving Science of Organization*, 149 J. Institutional & Theoretical Econ. 36, 47 (1993) ("Of special importance to Hayek was the proposition that the price system, as compared with central planning, is an extraordinarily efficient mechanism for communicating information and inducing change.").

as market definition, are simply aggregations of individual demand elasticities or preferences.[25] Market-oriented systems rely on the information provided by the intersection of supply and demand to allocate scarce social resources, thus ostensibly maximizing consumer wellbeing without any actor in the system needing to have direct knowledge about what consumers want or how they would make tradeoff decisions given scarcity. Markets are thus knowledge machines that produce vital utility maximization information more effectively than alternative institutions.

Another knowledge-producing function of competitive markets is the decentralized determination of which producers will perform which tasks. Here again, we can compare competitive markets to a system in which a central planner assigns jobs to different people. To maximize the performance of a productive system, the planner should assign jobs based on comparative advantage. But, as with consumer preferences, the planner is unlikely to have sufficiently robust information to make optimal assignments. Competitive markets solve that problem by spontaneously sorting producers. A firm that is less efficient than its competitors will not be able to survive long in a competitive market[26] and will have to eventually redeploy its capital to another market where it has a greater comparative advantage. Antitrust law tends to police conduct capable of excluding equally efficient competitors,[27] but it considers competition that excludes less efficient competitors to be a feature, rather than a bug, of a competitive market system.[28] Competitive markets thus direct the allocation of productive resources by determining who is best suited to perform which jobs.

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[25] William J. Baumol & Alan S. Blinder, Microeconomics: Principles and Policy 110 fig.5-3 (7th ed. 1997) ("[W]e obtain the market demand curve by adding horizontally all points on each consumer's demand curve at each given price.").

[26] *See* William M. Landes & Richard A. Posner, *Market Power in Antitrust Cases*, 94 Harv. L. Rev. 937, 977 (1981) (discussing the tendency of competitive markets to drive out less efficient producers); Chad Syverson, *Market Structure and Productivity: A Concrete Example*, 112 J. Pol. Econ. 1181, 1218 (2004) (providing an empirical example of enhanced competition in concrete markets leading to the exit of less efficient producers).

[27] *See, e.g.*, Cascade Health Sols. v. PeaceHealth, 515 F.3d 883, 900 (9th Cir. 2008) (adopting a rule governing bundled discounts that imposes "antitrust scrutiny only if [the bundled discounts] could exclude a hypothetically equally efficient competitor"); Barry Wright Corp. v. ITT Grinnell Corp., 724 F.2d 227, 232, 235–36 (1st Cir. 1983) (adopting predatory pricing rules based on consideration of which prices could exclude equally efficient competitors).

[28] *See, e.g.*, Hanson v. Shell Oil Co., 541 F.2d 1352, 1358–59 (9th Cir. 1976) ("The antitrust laws were not intended, and may not be used, to require businesses to price their products at unreasonably high prices (which penalize the consumer) so that less efficient competitors can stay in business. The Sherman Act is not a subsidy for inefficiency.").

B. Incentives

Competitive markets may provide information about how social resources should be allocated to optimize utility, but that alone is no guarantee that producers will act on the information to meet consumer demand. So, in addition to solving an information problem, competitive markets solve an incentives problem. As Adam Smith memorably observed, "[i]t is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest."[29] Competition drives producers to design and make things that consumers value and to offer them at low prices. In the landmark *Alcoa* case, Learned Hand justified economic competition as opposing the tendency of "unchallenged economic power [that] deadens initiative, discourages thrift and depresses energy."[30] Hand argued that "competition is a narcotic, and rivalry is a stimulant, to industrial progress; [and] that the spur of constant stress is necessary to counteract an inevitable disposition to let well enough alone."[31]

Although antitrust law is focused on creating optimal incentives, it does not usually operate directly on states of mind. It does not usually ask whether a producer intended to take actions that benefited consumers; instead, it asks whether the producer's actions are objectively consistent with beneficial competition or if they have the effect of harming competition.[32] As the D.C. Circuit explained in *Microsoft*, "our focus is upon the effect of that [allegedly anticompetitive] conduct, not upon the intent behind it. Evidence of the intent behind the conduct of a monopolist is relevant only to the extent it helps us understand the likely effect of the monopolist's conduct."[33] Similarly, Richard Posner has justified antitrust's reticence to place weight on subjective intent as necessitated by the difficulty of interpreting the available evidence against the backdrop of a legal standard that encourages aggressive competition.[34]

The assumptions that competition creates optimal incentives but that states of mind are too slippery to form the basis of competition policy

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29 1 Adam Smith, The Wealth of Nations 26–27 (R.H. Campbell et al. eds., 1976) (1776).

30 United States v. Aluminum Co. of Am. (*Alcoa*), 148 F.2d 416, 427 (2d Cir. 1945).

31 *Id.* ("Such people believe that competitors, versed in the craft as no consumer can be, will be quick to detect opportunities for saving and new shifts in production, and be eager to profit by them.").

32 Although courts usually avoid deciding antitrust cases based on the intentions of the defendants, specific intent to monopolize is an element of an attempted monopolization case because attempt offenses generally require a showing of specific intent to achieve the prohibited outcome. *See* Spectrum Sports, Inc. v. McQuillan, 506 U.S. 447, 459 (1993).

33 United States v. Microsoft Corp., 253 F.3d 34, 59 (D.C. Cir. 2001) (per curiam).

34 *See* Richard A. Posner, Antitrust Law 214–25 (2d ed. 2001).

undergird the antitrust order. Rather than operating directly on elusive and unreliable states of mind, antitrust operates on market structures and behaviors. Given the right structures and behavioral rules, firms will find that their profits are maximized when they deliver value to consumers. Thus, the antitrust order assumes that human states of mind are too opaque to control directly, but that deconcentrated markets and prohibitions on anticompetitive behaviors will push producers toward optimal production and pricing.

C. Structure

Central to the antitrust enterprise is the assumption that, even where markets are characterized by high fixed costs, entry barriers, network effects, or other structural features tending toward "natural monopoly," monopoly itself is usually not inevitable and can be prevented through enforcement of the antitrust laws.[35] Different versions of this axiom reflect different ideological perspectives but converge on a common belief that durable monopoly is never spontaneous, natural, or unavoidable. On the left, there is a tradition of minimizing claims that a large scale produces any significant efficiencies at all. Thus, Louis Brandeis and his followers on the Supreme Court argued that the efficiencies attributed to monopoly are largely illusory,[36] or that, if they exist at all, they are too small to mount a serious case for permitting monopoly.[37] To the right, Richard Posner argued that natural monopolies tend toward disintegration under the pressures of technological change.[38] Furthermore, even markets whose cost structure or other economic properties tend toward control by only a single dominant firm at a time are still subject to a form of competition—competition "for" the market rather than "in" the

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[35] *See* Steven C. Salop & R. Craig Romaine, *Preserving Monopoly: Economic Analysis, Legal Standards, and Microsoft*, 7 Geo. Mason L. Rev. 617, 621 n.9 (1999) (arguing that even where there are high entry barriers and demand-side economies of scale, monopoly is not inevitable).

[36] Louis Brandeis, *Shall We Abandon the Policy of Competition?* (1934), *reprinted in* The Making of Competition Policy, *supra* note 13, at 186 (arguing that monopoly efficiencies are "superficial and delusive"). Brandeis allowed that a "unit in business may be too small to be efficient," although "the unit may be too large to be efficient, and this is no uncommon incidence of monopoly." *Id.*

[37] *Id.* (arguing that any efficiencies generated by large-scale businesses tended to be absorbed by the businesses and not passed onto consumers).

[38] Richard A. Posner, *Natural Monopoly and Its Regulation*, 21 Stan. L. Rev. 548, 581 (1969) ("No natural monopoly can safely be assumed . . . to last forever, impervious to changes in technology and consumer taste.").

market.[39] As the D.C. Circuit observed in *Microsoft*, such winner-take-all markets may be characterized by temporary market dominance, but Schumpeterian competition for the market nonetheless occurs "sequentially over time rather than simultaneously across a market."[40] Thus, antitrust law rests on the assumption that markets are inherently capable of internal competition or, at a minimum, constant contestability by new entrants.[41]

Consistent with the belief that monopolistic market structures are avoidable, much of antitrust policy is focused on avoiding market concentration. Merger law prohibits combinations of capital that increase market concentration and that render market structures that facilitate collusion or outright monopolistic dominance.[42] Other branches of antitrust law, such as those governing competitor collaborations, joint ventures, and monopolization, are similarly concerned with preventing agreements or unilateral exclusionary conduct that have the effect of centralizing economic power in the hands of a single or small number of decisionmakers.[43] Thus, the goal of the antitrust laws is to prevent concentration of economic power in "too few hands," to "prevent . . . concentration," and "to preserve competition among a large number of sellers."[44] This is the goal, and the assumption is that it is attainable.

D. Conduct

As noted above, there has long been a debate within antitrust law about the relative prioritization of enforcement efforts focused on structure or conduct. The structuralists of the postwar era expressed a preference for targeting anticompetitive structures, whereas the Chicago School tended to argue that, if antitrust enforcement was needed at

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[39] *See* Harold Demsetz, *Why Regulate Utilities?*, 11 J.L. & Econ. 55, 57 & n.7 (1968) (discussing competition "*for* the field" rather than "*within* the field" in industries where there tends to be standardization on a single firm's technology); Gregory J. Werden, *Identifying Exclusionary Conduct Under Section 2: The "No Economic Sense" Test*, 73 Antitrust L.J. 413, 421 n.34 (2006) ("Monopoly is not inevitable just because a market is a natural monopoly, but it could be if enormously powerful network effects make competition 'for the market' rather than 'in the market.'").

[40] *Microsoft*, 253 F.3d at 49–50; *see also* Howard A. Shelanski & J. Gregory Sidak, *Antitrust Divestiture in Network Industries*, 68 U. Chi. L. Rev. 1, 83 n.356 (2001) (discussing the concept of "competition for a market").

[41] *See generally* Elizabeth E. Bailey & William J. Baumol, *Deregulation and the Theory of Contestable Markets*, 1 Yale J. on Regul. 111 (1984) (arguing that regulatory impediments to entry and exit, not concentration or scale, are the primary obstacles to effective competition).

[42] *See generally* U.S. Dep't of Just. & Fed. Trade Comm'n, Merger Guidelines (Dec. 18, 2023), https://www.ftc.gov/system/files/ftc_gov/pdf/2023_merger_guidelines_final_12.18.2023.pdf [https://perma.cc/3RKH-2XJQ].

[43] *See generally* Daniel A. Crane, Antitrust (2024).

[44] United States v. Von's Grocery Co., 384 U.S. 270, 274 (1966).

all to ensure competition, it could be more focused on interdicting anticompetitive behavior.[45] Similar debates have taken place in recent years across and within party lines on the question of structural versus behavioral remedies in merger and other antitrust cases. The Obama administration adopted merger remedy guidelines that encouraged behavioral remedies,[46] but the Trump and Biden administrations have exhibited a preference for structural remedies.[47]

Regardless of how a particular administration prioritizes structure or conduct, a sizable portion of antitrust enforcement consists of targeting anticompetitive behaviors such as price fixing and exclusionary behavior. The Supreme Court has referred to collusion as "the supreme evil of antitrust,"[48] and the Justice Department prosecutes it criminally.[49] The federal courts entertain hundreds of private and public lawsuits a year focused on a range of allegedly anticompetitive behaviors, finding liability in many cases. A treble damages remedy is provided to injured persons in order to deter those anticompetitive behaviors.[50] Debates continue over whether the available civil and criminal penalties for anticompetitive behaviors provide sufficient deterrence,[51] but the common assumption is that anticompetitive behavior is susceptible of being detected and punished. Without the assumptions that monopolistic structures can be prevented and that anticompetitive behaviors can be sanctioned, the antitrust system would make no sense, for those are the two functions it performs.

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45 *See* The Making of Competition Policy, *supra* note 13, at 390–92.

46 *See* U.S. Dep't of Just., Antitrust Division Policy Guide to Merger Remedies (June 2011), http://www.justice.gov/atr/public/guidelines/272350.pdf [https://perma.cc/W77K-UH7R].

47 Makan Delrahim, Assistant Att'y Gen., Antitrust Div., U.S. Dep't of Just., Antitrust and Deregulation, Remarks as Prepared for Delivery at American Bar Association Antitrust Section Fall Forum 5 (Nov. 16, 2017), https://www.justice.gov/opa/speech/file/1012086/download [https://perma.cc/6JED-E2LR] (arguing that "[i]nstead of protecting the competition that might be lost in an unlawful merger, a behavioral remedy supplants competition with regulation; it replaces disaggregated decision making with central planning"); Jonathan Kanter, Assistant Att'y Gen., Antitrust Div., U.S. Dep't of Just., Remarks as Prepared for Delivery at the New York State Bar Association Antitrust Section, https://www.justice.gov/opa/speech/assistant-attorney-general-jonathan-kanter-antitrust-division-delivers-remarks-new-york [https://perma.cc/9RL5-KELU] (asserting that the proper remedy for an anticompetitive merger is to block it, not to approve it with behavioral conditions or divestitures).

48 Verizon Commc'ns, Inc. v. Law Offs. of Curtis V. Trinko, LLP, 540 U.S. 398, 409 (2004).

49 *Criminal Enforcement*, Antitrust Div., U.S. Dep't of Just., https://www.justice.gov/atr/criminal-enforcement [https://perma.cc/JQC4-FDW2].

50 *See* 15 U.S.C. § 15.

51 *E.g.*, John M. Connor & Robert H. Lande, *Not Treble Damages: Cartel Recoveries Are Mostly Less Than Single Damages*, 100 Iowa L. Rev. 1997, 2018 (2015) (arguing, based on an empirical study showing that damages recoveries for cartels tend to be less than even single damages, that the damages multiplier should be increased).

II
The Coming Technological Wave

Much ink has been spilled on antitrust and AI, particularly on the topic of algorithmic collusion, which will be discussed in Section III.D below.[52] The coming technological revolution that threatens antitrust's four pillars will be empowered by AI but not limited to that technology. Following terminology suggested by Mustafa Suleyman, cofounder of the AI company DeepMind, this Article considers the likely effects on the antitrust order of a "coming wave" consisting of a set of overlapping, interdependent, and mutually reinforcing general-purpose technologies.[53] Suleyman argues that the coming wave will be centered on AI and synthetic biology but that "[t]echnological waves are bigger than just one or two general-purpose technologies," and that the wave will be generated by additional general-purpose technologies including robotics, quantum computing, energy expansion, and (in the more distant future) nanotechnology.[54] One may think of these emerging technologies as mutually amplifying waves which, in combination, result in a mega-wave that is set to have hugely disruptive effects on the organization of our economy, and hence on law, regulation, and the political order. This Part briefly introduces the key technologies and makes some preliminary comments about their interactions and economic implications.

A. Artificial Intelligence

In its most general sense, artificial intelligence is based, in the words of AI pioneer John McCarthy, on "the conjecture that every

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[52] *See, e.g.*, Zach Y. Brown & Alexander MacKay, *Competition in Pricing Algorithms*, 15 Am. Econ. J.: Microecon. 109 (2023); Joseph E. Harrington, Jr., *The Effect of Outsourcing Pricing Algorithms on Market Competition*, 2, 19 (July 19, 2021), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3798847 [https://perma.cc/34BZ-AK5J]; Simon Martin & Alexander Rasch, *Collusion by Algorithm: The Role of Unobserved Actions* (CESifo, Working Paper No. 9629, 2022); Jeanine Miklós-Thal & Catherine Tucker, *Collusion by Algorithm: Does Better Demand Prediction Facilitate Coordination Between Sellers?*, 65 Mgmt. Sci. 1552 (2019); Jason O'Connor & Nathan E. Wilson, *Reduced Demand Uncertainty and the Sustainability of Collusion: How AI Could Affect Competition* (Fed. Trade Comm'n Bureau of Econ., Working Paper No. 341, 2019); Shin-Shin Hua & Haydn Belfield, *AI & Antitrust: Reconciling Tensions Between Competition Law and Cooperative AI Development*, 23 Yale J. L. & Tech. 415 (2021); Daryl Lim, *Antitrust's AI Revolution*, 89 Tenn. L. Rev. 679, 722 (2022).

[53] Suleyman & Bhaskar, *supra* note 1; *see also* Gediminas Adomavicius, Jesse C. Bockstedt, Alok Gupta & Robert J. Kauffman, *Technology Roles and Paths of Influence in an Ecosystem Model of Technology Evolution*, 8 Info. Tech. Mgmt. 185 (2007) (proposing that "technology evolution is best viewed as a dynamic system or *ecosystem* that includes a variety of interrelated technologies") (emphasis in original).

[54] Suleyman & Bhaskar, *supra* note 1, at 91–102.

aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."[55] Although the possibility of computer intelligence was recognized in the 1950s, only more recently have AIs begun to equal or exceed functions performed through unaided human intelligence.[56] An umbrella term, AI describes a number of overlapping fields and technologies. Machine learning involves the use of statistical models and algorithms to iteratively improve a machine's predictions. Natural language processing, which includes applications like virtual assistants, chatbots, and machine translation, involves algorithms that analyze and interpret the syntax and semantics of human languages.[57] Computer vision allows computers to directly observe and interpret visual information contained in images and videos.[58] Neural networks aim to replicate the structure of the human brain by employing a network of nodes and internodal connections "in which designated weights represent the strength of the connections between nodes."[59] Deep learning allows those networks to capture complex and previously unobserved relationships within data sets.

Although AI promises to revolutionize standard economic assumptions,[60] we are currently in the technology's early ascendancy and far from its peak. The coming wave may involve both the dramatic expansion of AI's power as a technology and its adoption in the economic sphere as the brainpower that drives production and distribution.

On the technological side, AI exists for now in silos, capable of dramatically improving business performance on narrow, discrete tasks but not yet capable of serving as the brain comprehensively running a business or segment of the economy. Artificial General Intelligence ("AGI"), on the other hand, would be able to complete any intellectual task humans are capable of completing, and hence it could take over nearly completely from human planners and administrators.[61] Whether

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[55] John McCarthy, Marvin L. Minsky, Nathaniel Rochester & Claude E. Shannon, *A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence*, AI Mag. 13 (Aug. 31, 1955), http://www.aaai.org/ojs/index.php/aimagazine/article/view/1904/1802 [https://perma.cc/YT4A-W5K9].

[56] Henry A. Kissinger, Eric Schmidt & Daniel Huttenlocher, The Age of AI and Our Human Future 57 (2021).

[57] Bob Pellerin, AI Business Strategies: Leveraging Artificial Intelligence as Competitive Advantage 90–91 (2023).

[58] *What Is Computer Vision?*, Microsoft, https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-computer-vision [https://perma.cc/UE7H-426D].

[59] Kissinger, Schmidt & Huttenlocher, *supra* note 56, at 63.

[60] *See generally* Ajay Agrawal, Joshua Gans & Avi Goldfarb, Prediction Machines: The Simple Economics of Artificial Intelligence (2018) [hereinafter Prediction Machines].

[61] Kissinger, Schmidt & Huttenlocher, *supra* note 56, at 88.

AGI is truly possible, or what its characteristics would be, continues to be a subject of debate.[62] As it moves up the generality curve, AI will be implemented for an increasing number of interconnected functions within business organizations, amplifying the technology's economic effects.

That a new technology has demonstrated potential to transform an industry does not guarantee its widespread adoption overnight. As of the writing of this article, as to AI we are living in what Ajay Agrawal, Joshua Gans, and Avi Goldfarb call a "between times," the period between "the demonstration of the [disruptive] technology's capability and the realization of its promise reflected in widespread adoption."[63] They observe that, for electrical power, there was a forty-year period between the initial deployment of the technology and its widespread adoption.[64] Electricity was easily and quickly deployed for "point solutions," replacing a particular function within a wider system with a more efficient one, but it took far longer for electricity to be adopted for "system solutions," where the disruptive technology prompted a complete reconfiguration of the productive system.[65] Many businesses are beginning to adopt AI for point solutions, but few have yet reconfigured their entire systems in response to AI.[66] The AI revolution in business operations is unlikely to take the forty years it took electrical power, but at present, we are nowhere near the crest of the coming wave even in terms of technological development, much less in terms of systems solutions.

B. Synthetic Biology

Synthetic biology involves the "deliberate design and construction of a biological system to produce effects that would not ordinarily occur in nature."[67] Genetic engineering is an old technology—think of breeding animals—but the current wave of innovation in heredity, genetics, and bioengineering began in the 1970s and is on a sharply sloping development curve. Projects like the Human Genome Project, which achieved a mapping of most of the human genome by the early

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62 *Id.* at 88–89.

63 Ajay Agrawal, Joshua Gans & Avi Goldfarb, Power and Prediction: The Disruptive Economics of Artificial Intelligence 3–4 (2022).

64 *Id.* at 8.

65 *Id.* at 9.

66 *See* Victoria Uren & John S. Edwards, *Technology Readiness and the Organizational Journey Towards AI Adoption: An Empirical Study*, 68 Int'l J. Info. Mgmt. 102588 (2023), https://www.sciencedirect.com/science/article/pii/S0268401222001220 [https://perma.cc/9HS7-P7F4].

67 Robert Bolton & Richard Thomas, *Biohackers: The Science, Politics, and Economics of Synthetic Biology*, 9 Innovations 213, 213 (2014).

2000s, and technology like CRISPR, which allows direct editing of DNA sequences (and achieved a breakthrough in 2012), have led to a convergence between biology and engineering that is on "a sharp trajectory of falling costs and rising capabilities."[68] Food, medicines, materials, consumer goods, and many other commodities essential to human life will be radically reengineered in the coming years.[69]

The likely economic effects of synthetic biology are large. Most mundanely, the growth of synthetic biology is predicted to concentrate market structures in the biotechnology industry because of network effects and declining per-use costs.[70] This effect is explored further in Section III.C in conjunction with the concentrating effects of other technologies such as AI, robotics, and nanotechnology. But there is an even more potentially dramatic economic implication of synthetic biology—the reprogramming of the consumer. As explored in Section III.A, the advent of human synthetic biology implies a fundamental reconfiguration of what it means to be human, and, with that, of what it means for an economic system to discover the preferences of the human consumers the system is supposed to serve.

C. Robotics

A robot is a machine that is capable of replicating human actions independently of direct human operation. Robots need not be structurally anthropomorphic—autonomous vehicles, 3-D printers, construction machines, and robotic pollinators are all examples of robotic technologies that don't look like humans or animals but perform tasks previously performed by humans or animals (and usually much more efficiently).[71] Advanced robotic technology requires both physical engineering and rule specification, and on both those scores AI is driving robotics rapidly toward the place where robots "can replicate all the physical actions of a human and more."[72] Advanced robotics will have increasing economic implications over time, including one that is generating considerable social angst: the potential impacts on employment and job loss.[73] For purposes of this Article, increasing robotic functionality is primarily relevant as an amplifier of the market-concentrating effects of AI. Like synthetic biology, advances in robotics

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68 Suleyman & Bhaskar, *supra* note 1, at 79.

69 *Id.*

70 Joachim Henkel & Stephen M. Maurer, *The Economics of Synthetic Biology*, 3 Molecular Sys. Biology 1, 2 (2007).

71 Suleyman & Bhaskar, *supra* note 1, at 95–96.

72 *Id.* at 96.

73 *See* Jacques Bughin, *Why AI Isn't the Death of Jobs*, 59 Mass. Inst. Tech. Sloan Mgmt. Rev. 42 (2018).

will tend to concentrate production in a few large-scale organizations because of the large fixed costs and low marginal costs of designing and running a robotic system.

D. Quantum Computing

In 2019, Google announced that it had attained "quantum supremacy," the demonstration that a quantum computer has solved a problem that a conventional computer could not solve in a reasonable amount of time.[74] Quantum computers use the laws of quantum physics to perform functions that preexisting computers cannot handle. They are still in their infancy and have not yet reached practical, much less commercial, viability, but their long-term economic implications are enormous. Combined with AI and synthetic biology, quantum computing promises breakthroughs in fields such as pharmaceuticals, materials engineering, and industrial chemicals.[75] The economic implications of quantum computing are staggering. Any optimization problem might be solved far more quickly by a quantum computer than by either a conventional computer or a human brain, enabling any economic actor with access to quantum computing to leapfrog and displace rival actors.[76]

E. Energy Expansion

One of the principal factors limiting the development and proliferation of AI, synthetic biology, robotics, and quantum computing is that all of those technologies require immense amounts of computing power, which is costly in a direct economic sense and environmentally unsustainable given current energy technologies.[77] Breakthroughs in clean, renewable, and expandable energy such as fusion, solar, wind, and hydrogen energy as well as improved battery capacity could meet these needs.[78] These breakthroughs will allow the development and implementation of the other technologies in the coming wave to accelerate. Clean, renewable, and ample energy is, quite literally, the fuel that could drive the development, expansion, and deployment of the other coming wave technologies.

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74 *See* Franke Arute et al., *Quantum Supremacy Using a Programmable Superconducting Processor*, 574 NATURE 505, 505 (2019).

75 SULEYMAN & BHASKAR, *supra* note 1, at 99.

76 *See* Francesco Bova, Avi Goldfarb & Roger G. Melko, *Quantum Economic Advantage*, 69 MGMT. SCI. 1116, 1118 (2023) (discussing the baseline superior efficiency of quantum computing over classical computing).

77 *Id.* (describing the relationship between the demands of computational space and the execution of computational tasks).

78 SULEYMAN & BHASKAR, *supra* note 1, at 100–01.

F. Nanotechnology

Nanotechnology involves engineering at the molecular or atomic level.[79] Once the dream of the medieval alchemists, nanotechnology appears increasingly like a realistic rather than a magical technology. In 2020, a research team at Oxford produced a "rudimentary synthetic molecular assembler that produces polymers" in an assembly line-like process.[80] While commercialization may be decades away, the endpoint is a world in which "anything can become anything with the right atomic manipulation."[81] Suleyman observes that nanotechnology represents "the apotheosis of the bits/atoms relationship."[82] In a post-nanotechnology world, the possibility of rearranging one atomic structure into another one via computerized, energy-expanded, and robotic processes would mean that much of the economic value that currently resides in atomic structures (e.g., scarce natural resources) would migrate to the intelligent digital systems capable of reconstituting those structures. In short, general-purpose nanotechnology would mean the migration of most economic value from atoms to bits. Further, as discussed in greater detail in Section III.C below, since computer systems ("bits") are nearly infinitely scalable, general-purpose nanotechnology implies the concentration of physical production in a small number of smart robotic systems.

III
How the Four Pillars Will Buckle in the Coming Wave

The coming wave will not merely force companies to compete differently, as is already happening (for example, as companies increasingly invest in AI-driven technologies).[83] It will undermine the very reasons that they are required to compete and the state's techniques to ensure that they do. As the wave rolls, the four pillars on which the antitrust system is predicated—information, incentives, scale and scope, and conduct control—will begin to buckle. As the wave crests, they are likely to collapse entirely.

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79 K. Eric Drexler, Radical Abundance: How a Revolution in Nanotechnology Will Change Civilization 9–10 (2013).

80 Anthonius H.J. Engwerda & Stephen P. Fletcher, *A Molecular Assembler That Produces Polymers*, 11 Nature Commc'ns 1 (2020).

81 Suleyman & Bhaskar, *supra* note 1, at 101.

82 *Id.*

83 *See* Marco Iansiti & Karim R. Lakhani, Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World (2020).

A. Information

As discussed in Section I.A, competitive markets are often justified on the grounds that they produce real-time information about consumer demand and producer efficiency, which then translates seamlessly into a superior allocation of resources. The coming wave of general-purpose technologies will call into question this assumed advantage of competitive markets.

1. Consumer Preference

Hayek argued that a single mind never has sufficient information about individual wants and needs to be able to optimize economic allocation across all the complex and varied preferences of the individuals who comprise society.[84] But Hayek had in view a human mind, not a machine with a "God view"[85] of individual preferences. The coming technological wave will empower producers to anticipate and optimize consumer preferences without the need for price signals. Firms will have tremendously more information and predictive power about what customers value and how they would make tradeoff decisions given scarcity. As Agrawal, Gans, and Goldfarb have written, AI systems are essentially "prediction machines" that vastly improve predictive power over consumer preferences.[86] They observe that at some point, a retailer's AI system will "cross[] a threshold where it becomes so good that the folks at Amazon could ask: 'If we're so good at predicting what our customers want, then why are we waiting for them to order it? Let's just ship it.'"[87] The point is not facetious; Amazon has already patented an "anticipatory shipping" technology.[88] Although producers and retailers have not yet reached the place where they are routinely initiating consumer transactions without waiting for an affirmative consumer signal, the trend toward AI-empowered consumer insight and information will accelerate precipitously in coming years, with no clear endpoint in sight.

We do not have to wait for future technological developments to see the revolutionary potential of AI systems in predicting or detecting what individuals want. AI can already be used to analyze consumer data

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84 *See supra* text accompanying notes 18–23.

85 *See* Ariel Ezrachi & Maurice E. Stucke, Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy 72 (2016) (exploring how Uber's "God view" tracks consumers, showing the location of vehicles and consumers, and using this analogy to explore how competitors can use big data and analytics to gain an understanding of the marketplace).

86 *See* Prediction Machines, *supra* note 60, at 2–3.

87 *Id.* at 37.

88 Method & Sys. for Anticipatory Package Shipping, U.S. Patent No. 8,615,473 B2 (filed Aug. 24, 2012) (issued Dec. 24, 2013).

to provide companies with markedly better predictions or real-time data regarding consumer preferences.[89] For example, deep convolutional neural networks can forecast retail sales with far better precision than human managers.[90] A 2023 literature review of sixty-four empirical papers on AI and consumer behavior found that early adopters of AI for marketing and assessing consumer demand are using AI tools with increasing efficacy for a wide range of functions, including adding value to existing products and services, creating new products and services, and growing relationships with customers.[91] Use cases include, among many others, dynamic pricing, merchandise optimization, product information management, shelf optimization, and personalized content creation.[92] These techniques aim to replace a market's traditional discovery function by anticipating what consumers will want and how much they will be willing to pay for it and, in many cases, planning for delivery of personalized goods or services to the consumer before she makes her purchase decision.

Computer vision—the capacity of a computer to understand and interpret objects and people through direct visual observation—is revolutionizing the discovery of consumer preferences. As AI and computerized perception systems increasingly develop the capacity to analyze people's facial expressions rather than data about people, they will increasingly circumvent the need to rely on markets or price signals to discover consumer preferences with high degrees of precision. Disney's dramatic success with Disney Plus, which unexpectedly caught up to Netflix and Amazon Prime Streaming in 2023 after falling far behind, provides a salient example.[93] In order to predict whether new entertainment content would be popular with consumers, Disney

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[89] Mohamed Zaki, Janet R. McColl-Kennedy & Andy Neely, *Using AI to Track How Customers Feel—in Real Time*, Harv. Bus. Rev. (May 4, 2021), https://hbr.org/2021/05/using-ai-to-track-how-customers-feel-in-real-time [https://perma.cc/7CWX-LD4K].

[90] Shaohui Ma & Robert Fildes, *Retail Sales Forecasting with Meta-Learning*, 288 Eur. J. Operational Rsch. 111, 114 (2021) (proposing a meta-learning framework derived from deep convolutional neural networks that learns from forecasting performance and generates predictions of product sales according to data history). *See generally* Ming-Hui Huang & Roland T. Rust, *A Framework for Collaborative Artificial Intelligence in Marketing*, 98 J. Retailing 209 (2022) (detailing the impact of in-store AI upon retailing and the application of deep convolutional neural networks that forecast retail sales, in order to explore how best to leverage these tools).

[91] Rajat Gera & Alok Kumar, *Artificial Intelligence in Consumer Behaviour: A Systematic Literature Review of Empirical Research Papers Published in Marketing Journals (2000–2021)*, 27 Acad. Mktg. Stud. J. 1, 1 (2023).

[92] *Id.* at 2.

[93] *See* Pellerin, *supra* note 57, at 91 (noting how Disney Plus grew in popularity at a rate equivalent with Amazon Prime by virtue of AI, including the implementation of AI examinations of audience reactions during test screenings).

employed factorized variational autoencoders, which are a type of neural network that learns to reproduce its inputs, to analyze audience reactions during screenings in a 400-seat test theater.[94] Infrared light cameras captured over a million distinct facial variations, such as whether audience members were smiling, crying, bored, scared, or uncomfortable, which allowed Disney to determine "whether or not something was going to be a hit with every demographic, with no PR agency spin or personal bias involved."[95] More generally, AI methods are being developed at a rapid pace to detect and categorize human emotional responses through direct observation of speech (including such features as tone and loudness), face detection (for example, expressions conveyed through eyebrows, the tip of the nose, and the corners of the mouth) and various cues from both audio and video inputs.[96] Increasingly, producers do not need consumer surveys or price data to understand consumer demand. They can extract such information directly from the consumer. Indeed, they are increasingly able to understand a consumer's wants and needs before she can articulate those things herself and, perhaps, in ways that she cannot understand herself. AI-enabled systems are making rapid gains in determining and fulfilling consumer preferences, and they are just getting started.

The coming technological wave will not only enable productive systems to detect consumer preferences with far greater precision, it will allow those systems to fulfill consumer preferences in a much more tailored fashion. This is already occurring on a widespread basis in the digital world, where predictive engines allow media and entertainment content providers to customize consumer offerings.[97] Increasingly, developments in AI and robotics will enable customization across wide swaths of the economy. A new generation of "smart factories" will allow manufacturing systems to perceive external environments, adapt to external needs, dynamically optimize operations, and deliver goods in small, customized batches.[98] AI-driven productive systems will not only detect consumer preferences at a highly granular level, they will

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[94] *Id.* at 90; Zhiwei Deng et al., *Factorized Variational Autoencoders for Modeling Audience Reactions to Movies*, Disney Rsch. (July 21, 2017), https://la.disneyresearch.com/publication/factorized-variational-autoencoder [https://perma.cc/HZ8F-8ULW].

[95] *See* Pellerin, *supra* note 57, at 90–91.

[96] *See* Nantheera Anantrasirichai & David Bull, *Artificial Intelligence in the Creative Industries: A Review*, 55 A.I. Rev. 589, 629 (2022).

[97] *See, e.g.*, Yashar Deldjoo, Markus Schedlb & Peter Knees, *Content-Driven Music Recommendation: Evolution, State of the Art, and Challenges*, 51 Comp. Sci. Rev., art. 100618, 2024 (showcasing how music recommendation models have become pervasive).

[98] *See generally* Jiafu Wan, Xiaomin Li, Hong-Ning Dai, Andrew Kusiak, Miguel Martínez-García & Di Li, *Artificial-Intelligence-Driven Customized Manufacturing: Key Technologies, Applications, and Challenges*, 109 Procs. IEEE 377 (2021).

increasingly be able to deliver differentiated, bespoke output matching individual consumers' preferences.[99]

That AI and related technologies will enable much more accurate prediction and fulfillment of consumer preferences and hence consumer demand than any previous technology is a given, but the eventual effect of AI and related technologies is likely to go well beyond providing predictive information about consumer preferences. Looking pessimistically, AI may "interfer[e] with the formation of consumer preferences."[100] Looking analytically, AI and other technologies of the coming wave are likely to go even further than merely influencing consumer preferences—they may soon begin to directly program consumer preferences.

Consider the imminent prospect of human synthetic biology. The advent of CRISPR technology, now barely a decade old, is empowering the direct editing of gene sequencing to develop treatments for a wide variety of human conditions.[101] DNA synthesizers, enhanced by advances in computational power and AI, will before long enable dramatic enhancements in our ability to rewrite the code of life.[102] Potential applications of these technologies include reversing the aging process, reconfiguring human genetics to enhance immune responses, and delivering medicines that are precisely tailored to a patient's biomarkers.[103] Beyond genetic engineering, companies like Neuralink are working on brain-interfacing technology and implants that connect the human brain directly to computer systems.[104] Reflecting on these rapidly scaling technologies, Suleyman asks, "What happens when a human mind has instantaneous access to computation and information on the scale of the internet and the cloud?"[105]

One answer to Suleyman's question is that the line between the will of the human agent and the technological systems that structure and program it will become blurred. Subject to ethical and political constraints, the coming technological wave may call into question the idea that consumers have demand functions that are separate from the systems that write a consumer's genetic code, program her brain, or curate,

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99 *See, e.g.*, Xingzhi Wang, Ang Liu & Sami Kara, *Machine Learning for Engineering Design Toward Smart Customization: A Systematic Review*, 65 J. Mfg. Sys. 391 (2022) (reviewing existing literature to identify trends in customized engineering design).

100 Stuart Mills, Samuel Costa & Cass R. Sunstein, *AI, Behavioural Science, and Consumer Welfare*, 46 J. Consumer Pol'y 387, 388 (2023).

101 *See* Suleyman & Bhaskar, *supra* note 1, at 82–83.

102 *See id.* at 83.

103 *Id.* at 85.

104 *Id.* at 91.

105 *Id.*

organize, and present the set of informational stimuli that shape her preferences. As Eric Posner and Glen Weyl have written, once the computer "plans" the consumer, the comparative advantage of markets in discovering consumer preference dissipates.[106] Although there may be resistance to acknowledging that consumer demand is something created rather than found, realistically, consumer demand is likely to shift from an exogenous fact that production and distribution systems seek to discover to being shaped or even created by the production and distribution system itself. In such an increasingly likely scenario, it is hard to see why price signals are necessary to discover the consumer's preferences. The consumer's preferences will be both an input and output of the system.

In its most extreme version, this argument takes a hyperdeterminist side against the possibility of human free will. But neither the technology nor its philosophical implications need run to the limit in order to call into question the conventional view that markets are necessary to discovering consumer preferences. Even if human preferences remain subject to a core of idiosyncratic individual will, untainted and uncontrolled by genetic or technological programming, technological advances are very likely to make human will—and hence its demand functions—far more revealed and less mysterious. We will be able to make far better predictions about what consumers want and need, and therefore we will know how to make optimal decisions about resource allocations better than ever before in human history.

To be sure, an economic system driven by technologies that directly extract or, in the extreme, directly program consumer preferences will impose costs. Even if algorithmic systems can improve consumer outcomes by giving consumers more of what they want, consumers may experience these systems as an intrusion on their autonomy.[107] The systems also might make mistakes by misidentifying consumer preferences. For example, when multiple algorithmic systems rely on the same components, such as the same training data or machine learning models, they can tend toward an "algorithmic monoculture" in which

106 Eric A. Posner & E. Glen Weyl, Radical Markets 288–93 (2018).

107 *See, e.g.*, Michael R. Hyman, Alena Kostyk & David Trafimow, *True Consumer Autonomy: A Formalization and Implications*, 183 J. Bus. Ethics 841 (2023) (attempting to formalize a definition of consumer autonomy through performance theory mathematics); Quentin André et al., *Consumer Choice and Autonomy in the Age of Artificial Intelligence and Big Data*, 5 Customer Needs & Sols. 28 (2017) (discussing how artificial intelligence could enhance or diminish perceptions of consumer control over their own actions).

outcomes are homogenized, which may result in compounding errors across an entire system.[108]

But it is important to remember that the case for market competition has never rested on perfection, but rather on comparative advantage. AI-driven systems may never—or not for a long time—provide *perfect* information necessary to the optimal allocation of social resources, but they only have to *outperform* markets to replace them. We are on a quick path to a point where AI-driven systems may provide much better information than competitive market price signals. Even if the information is not actually more accurate than competitive market signals, it may be perceived as more accurate by businesses, consumers, and regulators. The case for competitive markets has never been that markets produce valuable information costlessly. To the contrary, competition is often wasteful.[109] As Justice Douglas recognized, quoting Brandeis in his *Columbia Steel* dissent, "[u]ndoubtedly competition involves waste."[110] But, for Douglas and Brandeis, the waste of competition is "relatively insignificant" compared to other kinds of waste that democratic societies tolerate.[111] To the extent that the antitrust order is predicated on the view that competitive markets generate necessary information about consumer preferences more efficiently than other modalities, that view is about to be seriously challenged by the coming technological wave.

2. *Productive Efficiency*

The second discovery function of competitive markets is to identify the most efficient firms or producers and steer less efficient ones toward business activities in which they enjoy a greater comparative advantage. As with discovery of consumer preferences, the coming technological wave will dramatically increase the economic system's ability to observe comparative productive efficiency directly, without waiting for information revealed indirectly by competition and price signals.

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[108] *See generally* Rishi Bommasani, Kathleen A. Creel, Ananya Kumar, Dan Jurafsky & Percy Liang, *Picking on the Same Person: Does Algorithmic Monoculture Lead to Outcome Homogenization?*, 35 Advances in Neural Info. Processing Sys. 3663 (2022).

[109] *See, e.g.*, Alfred E. Kahn, 2 The Economics of Regulation: Principles and Institutions 123 (1971) (explaining that overlapping providers of infrastructure services like telephone service would require consumers to pay for "two instruments, two lines into his home, two bills").

[110] United States. v. Columbia Steel Co., 334 U.S. 495, 534 n.1 (1948) (Douglas, J., dissenting) (citing Louis Brandeis, The Curse of Bigness: Miscellaneous Papers of Louis Brandeis (1934)).

[111] *Id.*

Predicting AI's path toward direct monitoring of productive efficiency is complicated by the fact that the boundaries of firms and external markets are likely to shift significantly in the coming years. Following Coase, the boundaries of a firm are typically determined by the relative transaction costs of performing a function internally within the firm compared to those of purchasing it in an external market.[112] AI and related digital technologies are already reshaping the traditional boundaries of firms by changing the relative transaction costs of both internal monitoring and external transacting.[113] Whether economic functions end up being performed within the firm or outside its borders, AI is enabling firms to gather significantly enhanced information on comparative performance. Employers are making extensive use of AI to track employee behavior, automate performance evaluations, recommend job improvements, supervise employees, and shift workloads.[114] On the external side, firms are making increasing use of AI for evaluating the efficiency of suppliers through AI-enabled supplier scouting technologies.[115] As AI and machine learning grow exponentially in capacity and use cases, it will be increasingly possible to determine the comparative efficiency and performance of economic actors by observing them directly.

This point about the role of AI in discovering productive efficiency should be paired with the point made below in Section II.C about the propensity of the coming wave to create megafirms because of nearly limitless increasing returns to scale and scope. As a small number of megafirms roll up much of the economy, the question will arise as to how those firms will be able to manage their internal allocation of resources

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112 *See* Ronald H. Coase, *The Nature of the Firm*, 4 ECONOMICA 386, 390–91 (1937).

113 *See e.g.*, Dirk Nicolas Wagner, *The Nature of the Artificially Intelligent Firm – An Economic Investigation into Changes AI Brings to the Firm*, 44 TELECOMM. POL'Y (2020) (arguing that AI reshapes the boundaries of firms by introducing new forms of information asymmetries, creating new agency relationships, and removing traditional limits to integration); *see also* Markus Menz et al., *Corporate Strategy and the Theory of the Firm in the Digital Age*, 58 J. MGMT. STUD. 1695, 1697 (2021) (citing studies on the effects of technologies such as digitalization and the blockchain in reshaping firm boundaries).

114 *See, e.g.*, Prabhat Mittal, Rachna Bansal Jora, Kavneet Kaur Sodhi & Parul Saxena, *A Review of the Role of Artificial Intelligence in Employee Engagement*, 9TH INT'L CONF. ON ADVANCED COMPUTING & COMMC'N SYS. 819 (2023); *see also* Siliang Tong, Nan Jia, Xueming Luo & Zheng Fang, *The Janus Face of Artificial Intelligence Feedback: Deployment Versus Disclosure Effects on Employee Performance*, 42 STRATEGIC MGMT. J. 1600, 1600–01 (2020); *see also* Lionel P. Robert, Casey Pierce, Liz Marquis, Sangmi Kim & Rasha Alahmad, *Designing Fair AI for Managing Employees in Organizations: A Review, Critique, and Design Agenda*, 35 HUM.-COMPUT. INTERACTION 544, 545 (2020).

115 Michela Guida, Federico Caniato, Antonella Moretto & Stefano Ronchi, *Artificial Intelligence for Supplier Scouting: An Information Processing Theory Approach*, 20 INT'L J. PHYSICAL DISTRIB. & LOGISTICS MGMT. 387 (2023) (discussing the use of AI by firms to evaluate suppliers and determine their efficiency at fulfilling orders).

optimally. In competitive economies, firms can benchmark the efficiency of their internal operations to similar functions available for purchase in external markets. In an economy dominated by a few megafirms, that may no longer be possible. However, because of AI's power to directly discover efficiency, it may also no longer be necessary. To the extent that market competition is understood to provide otherwise unavailable information on productive performance, the new technologies will increasingly render that function obsolete.

B. Incentives and Processes

The second pillar of the antitrust order is the assumption that market competition provides optimal incentives for firms to deliver value to consumers, especially by lowering prices, increasing output, innovating, and offering high-quality products and services. Since states of mind and motivations are difficult to detect or interpret, antitrust law instead scrutinizes firm behavior to determine whether the firm's conduct is consistent with the firm acting competitively or anticompetitively.[116] Intentions are opaque, but processes are transparent—therefore, antitrust focuses on processes.

With AI-driven systems, the story is just the opposite: intentions are transparent, and processes are opaque. Of course, machines do not literally have intentions, but they do have objective functions: the mathematical functions that describe an optimization problem that machine learning is used to solve. For example, as explored further in Section III.D, companies are increasingly delegating pricing decisions to algorithms.[117] A price-setting algorithm must be told what problem to solve, and what problem it is told to solve strictly determines what problem it actually solves. For example, a pricing algorithm that is programmed to learn asynchronously (based solely on the returns from the actions it took) will tend to implement monopoly prices, whereas algorithms programmed to update synchronously (based both on the returns from the actions it took and also on the returns from counterfactual actions it did not take) will tend to implement competitive prices.[118] Small changes in an algorithm's design—what it is told to do—can imply large changes in the prices it sets.[119] Unlike a

116 *See supra* text accompanying note 32.

117 *See* John Asker, Chaim Fershtman & Ariel Pakes, *Artificial Intelligence and Pricing: The Impact of Algorithm Design* 1 (Nat'l Bureau of Econ. Rsch., Working Paper No. 28535, 2021), http://www.nber.org/papers/w28535 [https://perma.cc/933D-ED24].

118 *Id.* at 6.

119 *See* J. Manuel Sanchez-Cartas & Engelos Katsamakas, *Artificial Intelligence, Algorithmic Competition and Market Structure*, 10 IEEE Access 10575, 10583 (2022), https://ieeexplore.ieee.org/document/9684893 [https://perma.cc/GEU8-P25C].

human actor, an AI's "intentions" are perfectly clear and discernible once one has access to its objective function.[120]

On the other hand, an AI-driven system's processes—the steps it takes to implement its objective function—are notoriously opaque. As Henry Kissinger, Eric Schmidt, and Daniel Huttenlocher write, AI platforms operate in ways that are "nonhuman, and, in many ways, inscrutable to humans."[121] Thus, while Google engineers might find that AI-enabled search functions produce superior results than without AI, they cannot explain the mechanism by which this occurs.[122] AI-driven operations thus involve a shift from human-mediated operations, in which processes "could be paused, inspected, and repeated by human beings," to operations that produce outcomes whose operational steps are opaque.[123] Suleyman notes that "[i]n AI, the neural networks moving toward autonomy are, at present, not explainable."[124] Models like those in ChatGPT and AlphaGo are black boxes with "outputs and decisions based on opaque and intricate chains of minute signals."[125] While a very general explanation of what a system has done may be possible, it is not possible to break down the system's actions into anything like the set of identifiable and understandable steps that are possible with respect to a human actor.

AI's black-box nature poses considerable challenges for institutions like the justice system, whose legitimacy is founded on reason-giving,[126] and for ensuring social trust in the outcome of AI processes.[127] Some AI theorists, designers, and practitioners purport to be at work trying to find techniques to provide intelligible explanations of AI

120 *See* Sendhil Mullaimathan, *Biased Algorithms Are Easier to Fix Than Biased People*, N.Y. Times (Dec. 6, 2019) https://www.nytimes.com/2019/12/06/business/algorithm-bias-fix.html [https://perma.cc/8JXE-WFRS] ("Humans are inscrutable in a way that algorithms are not.").

121 Kissinger, Schmidt & Huttenlocher, *supra* note 56, at 107.

122 *Id.*

123 *See id.* at 107, 109, 185.

124 Suleyman & Bhaskar, *supra* note 1, at 114.

125 *Id.*

126 *See* Margot E. Kaminski & Jennifer M. Urban, *The Right to Contest AI*, 121 Colum. L. Rev. 1957, 2002–03 (2021) (discussing the essentiality of reason-giving in contested legal proceedings); *see also* Yavar Bathaee, *The Artificial Intelligence Black Box and the Failure of Intent and Causation*, 31 Harv. J.L. & Tech. 889, 891 (2018) ("AI that relies on machine-learning algorithms, such as deep neural networks, can be as difficult to understand as the human brain.").

127 *See* Warren J. von Eschenbach, *Transparency and the Black Box Problem: Why We Do Not Trust AI*, 34 Phil. & Tech. 1607 (2021) (arguing that AI systems that use deep learning in ways that prevent humans from understanding the processes that generate decisions create trustworthiness problems).

decision-making.[128] However, there is no guarantee that these efforts will be successful, and enhancements in deep neural networks and other AI technologies could lead to even greater opacity as to the system's functional steps.[129]

The opacity of AI's "decision-making" nature poses both justificatory and operational challenges for antitrust law. The operational challenges are discussed in Section III.D. The justificatory challenges concern the assumption that market competition is necessary to optimize incentives. To be sure, human beings have to write an algorithmic system's commands, and competitive stimuli might induce them to write commands that better suit social purposes, but the objective functions themselves can be directly scrutinized (through compulsory legal processes, if necessary) and have objectively determinable implications regardless of the subjective intentions of the programmers.[130] Once a regulator or court has in view an AI's objective functions and the expertise to interpret them, it knows all it needs to know—and, given the opacity of the AI's operations, all that it may ever know—about whether or not the productive system will behave "competitively." At that point, "competitively" loses saliency. If competition was deemed desirable because it induced firms to behave virtuously (e.g., by lowering prices and increasing quality), once it can be directly judged whether an AI has been instructed to behave virtuously or unvirtuously, whether or not the objective function is "competitive" becomes rather beside the point, and perhaps even unintelligible. The ultimate question is whether the algorithmic system has been programmed to produce socially desirable outcomes. At the limit, AI thus renders competition—the organizing principle of antitrust law—superfluous.

This argument may seem facile because of the assumption that it is straightforward to determine whether an AI-driven system's objective functions imply socially desirable outcomes. Let's stipulate that such a

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128 *E.g.*, Dino Pedreschi et al., *Meaningful Explanations of Black Box AI Decision Systems*, 33 Proc. of the AAAI Conf. on A.I. 9780, 9780 (2019) (advocating for a system of AI explanation through "inference of local explanations for revealing the decision rationale for a specific case, by auditing the black box in the vicinity of the target instance"); *see also* Arun Rai, *Explainable AI: From Black Box to Glass Box*, 48 J. Acad. Mktg. Sci. 137 (2019) (discussing recent advances in "post-hoc interpretability techniques").

129 Bathaee, *supra* note 126, at 893–94 (observing that "there is no guarantee certain AI programs and machine-learning algorithms can be developed with increased transparency," and that "[t]he future may in fact bring even more complexity and therefore less transparency in AI, turning the transparency regulation into a functional prohibition on certain classes of AI that inherently lack transparency").

130 This is not to say that discerning an AI's objective function allows an easy prediction of the AI's outputs, which depend heavily on the data the AI ingests and the operations of its algorithms.

task will be immensely challenging. Even so, continuing to scrutinize AI systems as though they were natural persons needing to be incentivized to behave competitively makes little sense as an alternative. An AI cannot be incentivized in a human sense,[131] only programmed, and whether it is behaving "competitively" or "anticompetitively" would require access to a set of processing steps that are invisible. The antitrust system was built with human actors in mind, and it begins to lose its purchase as applied to machines.

C. Scale and Scope

We turn now from the two pillars justifying antitrust law as mandating market competition to the two pillars concerning the operations of the antitrust system. The first of those comprises two assumptions: first, that large-scale or monopolistic enterprise is avoidable through the vigilant application of the antitrust laws, and second, that any losses of efficiency from mandating a decentralized economy are sufficiently slight that an anti-concentration agenda will not be perceived as excessively costly. The technologies of the coming wave will seriously challenge those assumptions.

That technological changes can drive markets toward increasing concentration and market power is not a new story.[132] The Sherman Act itself was a reaction to the industrial consolidation caused by the Second Industrial Revolution.[133] Over the past several decades, advances in information technology have driven increases in concentration in the U.S. economy.[134] More recently, network effects, scale economies, and

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131 An unsupervised machine learning system could be said to be "incentivized," given that it is "rewarded" when it performs well. But none of that is exogenous to the programming of the machine. The system has no goals, aspirations, desires, or preferences outside of those that it is programmed to have.

132 *See generally* JOHN SUTTON, TECHNOLOGY AND MARKET STRUCTURE: THEORY AND HISTORY (1998) (showing that technological innovations tend to increase the minimum efficient scale for participation in a market and thus can lead to increases in concentration and long-term market power).

133 *See generally* ALFRED D. CHANDLER JR., SCALE AND SCOPE: THE DYNAMICS OF INDUSTRIAL CAPITALISM ch. 3 (1990) (describing the impact of the Second Industrial Revolution on the growth of American industry and its impact on the passage of the Sherman Act).

134 *See, e.g.*, Chang-Tai Hsieh & Esteban Rossi-Hansberg, *The Industrial Revolution in Services* 1 (Nat'l Bureau of Econ. Rsch., Working Paper No. 25968, 2019), http://www.nber.org/papers/w25968 [https://perma.cc/3DPR-Z3RC] (arguing that increases in concentration are "consistent with the availability of a new set of fixed-cost technologies that enable adopters to produce at lower marginal costs in all markets"); *see also* Thomas Philippon, *The Economics and Politics of Market Concentration*, NBER REPORTER, Dec. 2019, at 10 (noting that "business concentration . . . [has] increased across most industries in the United States over the past 20 years"); Erik Brynjolfsson, Wang Jin & Xiupeng Wang, *Information Technology, Firm Size, and Industrial Concentration* (Nat'l Bureau of Econ. Rsch., Working

the ubiquitous competitive advantages arising from large data sets have driven the tremendous growth of large technology companies.[135] The coming technological wave promises to dramatically accelerate the trend toward the market dominance of a small number of firms, with no logical endpoint or likelihood of reversal.

Like other digital technologies, AI-driven systems are subject to strong positive network effects, in which the utility of the platform to all users increases with the number of users.[136] But, unlike prior digital technologies,[137] it is hard to see a point at which returns to scale become negative.[138] As AI and machine learning systems ingest increasing volumes of data, their algorithmic outcomes improve, which in turn allows their business outputs to improve, which in turn allows them to ingest more data, which in turn generates better business outputs, and so forth in a seemingly limitless virtuous cycle.[139] Thus, Marco Iansiti and Karim Lakhani argue that "[a]lgorithm-driven operating models are . . . almost infinitely scalable, as long as you can continue to add computing and storage capacity to the technology infrastructure," and that low-marginal-cost computing capacity and storage capacity are

Paper No. 31065, 2023), https://www.nber.org/papers/w31065 [https://perma.cc/RSH5-4ELW] (highlighting how advances in IT technology contribute to concentration).

135 *See* A. Douglas Melamed, *Antitrust Law and its Critics*, 83 Antitrust L.J. 269, 269 (2020) (noting that the technology industry "provokes unease because its power seems to expand without limit through scale and scope economies and network effects . . . [and] because it aggregates data and threatens privacy").

136 Kissinger, Schmidt & Huttenlocher, *supra* note 56, at 102–04.

137 *See* William J. Kolasky, *Network Effects: A Contrarian View*, 7 Geo. Mason L. Rev. 577, 586–87 (1999) (discussing how network effects in digital platforms are subject to diminishing returns to scale because of saturation and congestion); *see also* Alan Devlin, *Analyzing Monopoly Power Ex Ante*, 5 N.Y.U. J.L. & Bus. 153, 187 (2009) (discussing circumstances in which industries characterized by initially strong network effects can exhibit diminishing returns to scale); *see also* Michael S. Barr, *Banking the Poor*, 21 Yale. J. on Regul. 121, 202 (2004) (discussing ways in which "network effects may experience diminishing marginal returns to scale after a critical mass is reached").

138 Of course, as an AI's predictions as to a particular problem approach perfection, further machine learning cannot much improve the AI's performance. *See* Hal Varian, *Artificial Intelligence, Economics, and Industrial Organization*, *in* Ajay Agrawal, Joshua Gans & Avi Goldfarb, The Economics of Artificial Intelligence: An Agenda 406 (2019). Thus, if the AI's objective function is to achieve something simple like distinguishing dogs from cats, a number of competitive AIs could reach near perfection and have no advantage over the others. But most commercially important applications of AI are far more complex and dynamic than that sort of binary and static question.

139 Iansiti & Lakhani, *supra* note 83, at 97; *see also* Roxana Mihet & Thomas Philippon, *The Economics of Big Data and Artificial Intelligence*, 20 Int'l Fin. Rev. 29, 30 (2019) (discussing the tendencies of big data and AI to be produced under increasing returns to scale); *see also* Tejas N. Narechania, *Machine Learning as Natural Monopoly*, 107 Iowa L. Rev. 1543, 1584–85 (2022) (describing how machine learning's virtuous cycle tends toward natural monopoly).

increasingly facilitated by the shift to cloud computing.[140] As network and learning effects accelerate, "the viability of competitive alternatives is diminished, and markets are driven toward concentration."[141] Other technologies of the coming wave will likely amplify these market-concentrating effects. Robotic or automated production will result in a continued shift toward high-fixed-cost, low-marginal-cost production, with the implication that dominant technologies will be highly scalable and displace traditional production based on human capital and labor inputs.[142] Firms with a comparative advantage brought about by quantum computing may obtain an insurmountable lead over firms that continue to rely on conventional computing and human intelligence.[143] Firms that are able to engage in atomically precise manufacturing and create new synthetic compounds that far outstrip conventional production processes and materials in both cost and functionality will rapidly displace competitors that use conventional production methods and materials.[144] In combination, the potential arises for economies of scale to stretch toward infinity, or at least far beyond the economic event horizon where the dominant firms' gravitational attraction collapses the entire market.[145]

AI will not only tend to concentrate power in a dominant producer but may also tend to make that dominant producer relatively impervious to leapfrogging by external challengers. AI systems involve hyper-speedy feedback loops, which means that the first firm to market may obtain a durable advantage that increases over time.[146] For example, despite being well-financed by a major technology company that was already a monopolist in several digital fields, Microsoft's Bing search engine has struggled to catch up with Google.[147] Google's AI-powered search engine with millions of daily users and billions of searches updates its predictive capacity in real time, which makes it extraordinarily difficult for rivals to supplant.[148] Many technologies involve first-mover

140 Iansiti & Lakhani, *supra* note 83, at 96.

141 *Id.* at 161.

142 *See* Hamid Firooz, Zheng Liu & Yajie Wang, *Automation and the Rise of Superstar Firms*, (S.F. Fed. Reserve, Working Paper No. 2022-05, 2023), https://www.frbsf.org/economic-research/publications/working-papers/2022/05 [https://perma.cc/YUW8-FQF4] (reporting that automation leads to arrival of "superstar firms" that dominate their markets).

143 *See supra* text accompanying notes 75–76.

144 Drexler, *supra* note 79, at 244.

145 Kate Crawford, Atlas of AI 211 (2021) (arguing that AI systems have the tendency of "centraliz[ing] control for those who wield them").

146 Agrawal, Gans & Goldfarb, *supra* note 63, at 126–27.

147 *See id.* at 64; Iansiti & Lakhani, *supra* note 83, at ch. 6.

148 *See* Iansiti & Lakhani, *supra* note 83, at ch. 6.

advantages, but those in AI systems seem to be of a different magnitude altogether.

The exact shape of AI's scale economy curve—and, particularly, the importance of big data in improving the performance of AI-driven productions systems—remains to be seen.[149] Returns to scale may flatten at some point, which would create the necessary conditions for multiple competitive systems.[150] However, another economic feature of AI-driven systems—economies of scope—will also drive markets toward concentration. Just as AI-driven systems may operate with seemingly unbounded returns to scale for some period of time, they may also operate with seemingly unbounded increasing returns to scope.

A key feature of machine learning that differentiates it from prior technological innovations is its ubiquitous application to seemingly different problems by virtue of an AI system's ability to make predictions based on underlying patterns that were invisible to human agents.[151] To a human production team, optimizing the design of an automobile versus the design of a shoe may seem like very different problems. To an AI, they may be much more similar problems requiring similar predictive optimization techniques. This implies that an AI production system that achieves market dominance because it is very good at one task can be leveraged into many other fields with similar success.

How far AI's economies of scope will reach depends in large part on the question previously raised: How far can AI progress from specialized intelligence to general intelligence?[152] AI competitions and benchmarks are increasingly pushing AI systems to pursue all-purpose capability.[153] The open question is whether AI systems will perform more poorly as they become more general, or whether, to the contrary, systems "that are better for some tasks will also be better for other tasks."[154] As to human intelligence, Spearman's (somewhat controversial) law of diminishing returns holds that the highest-performing individuals will

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149 Thibault Schrepel & Alex 'Sandy' Pentland, *Competition Between AI Foundation Models: Dynamics and Policy Recommendations* 9 (MIT Connection Sci. Working Paper No. 1-2023, 2023) (reporting that "recent technical developments are increasing the importance of the efficiency of AI models, while proportionally decreasing the importance of ever-larger data sets").

150 *See id.* at 14.

151 *See* Bartosz Brożek, Michał Furman, Marek Jakubiec & Bartłłomiej Kucharzyk, *The Black Box Problem Revisited. Real and Imaginary Challenges for Automated Legal Decision Making*, 32 A.I. & L. 427, 436 (2024) ("[AI algorithms] were designed to find patterns in datasets which cannot be analyzed by humans with their limited computational capacities.").

152 *See supra* notes 60–66 and accompanying text.

153 José Hernández-Orallo, *AI Generality and Spearman's Law of Diminishing Returns*, 64 J. A.I. Rsch. 529, 529 (2019).

154 *Id.* at 530.

not be as good in other tasks as the ones in which they excel, which implies that a high degree of specialization is necessary for a high level of performance.[155] Will that principle of human intelligence hold as to *artificial* intelligence? A 2019 study on an AI's performance found no diminishment in the system's performance as it, for example, learned to play new video games.[156] Contrary to the operation of human intelligence, an AI system that is the best at doing one task may also be the best at doing a number of other tasks—which implies very strong economies of scope.

As AI enters its general-purpose or "omni-use" phase, its applications will move out of discrete information-oriented silos to "permeate[] and power[] almost every aspect of daily life."[157] The same machine learning and robotic processes that already dominate large swaths of the economy will continue to spread to adjacent domains not typically thought of as the province of computers or automated production, with the effect of increasingly consolidating previously separate economic functions.[158] For example, an AI system initially designed to write insurance products might be able to learn to prevent fires, then to build homes, then to build cars, then to build airplanes, and so forth. As with economies of scale, these increasing returns to scope need not be infinite in order to concentrate planning, production, and distribution in a few firms.[159] It is enough that scores or hundreds of previously unrelated economic tasks will become related by the expanding reach of AI technologies that are able to recognize common underlying patterns that were previously outside the cognition of human agents.

Here again, AI's market-concentrating effects will be amplified by the other technologies of the coming wave. At the limit, the combination

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155 *See* Charles E. Spearman, The Abilities of Man: Their Nature and Measurement 219 (1927); *see also id.* at 531 (explaining that Spearman's law implies that "humans could achieve more overall performance by the integration of advanced specific skills rather than the improvement of general skills").

156 Hernández-Orallo, *supra* note 153, at 536–38.

157 Suleyman & Bhaskar, *supra* note 1, at 116–18.

158 Jai Vipra & Anton Korinek, *Market Concentration Implications of Foundation Models: The Invisible Hand of ChatGPT* 2 (Brookings Inst. Ctr. on Regul. & Mkts. Working Paper, Paper No. 9, 2023) ("The negative implications of excessive concentration and lack of contestability in the market for foundation models include the standard monopoly distortions, ranging from restricted supply and higher prices to the resulting implications for the concentration of economic power and inequality.").

159 The principal obstacle to the expansion of deep learning to adjacent domains appears to be limited computing power. *See* Neil C. Thompson, Kristjan Greenewald, Keeheon Lee & Gabriel F. Manso, *Deep Learning's Diminishing Returns: The Cost of Improvement Is Becoming Unsustainable*, IEEE Spectrum, Sept. 24, 2021, at 52. That limitation may be addressed by quantum computing.

of AI, energy expansion, genetic engineering, quantum computing, and (in the distant but not unforeseeable future) nanotechnology empowering atomically precise manufacturing[160] could entail a transition of nearly all economic value from atoms to bits. (Think of the Star Trek "replicator," where economic value lies exclusively in the computer and robotic system that allows the on-command generation of almost any physically possible combination of atoms that the consumer demands.)[161] Even far short of these extreme but plausible sci-fi scenarios, the implication for market structure and competition from existing technologies and trends is the inexorable growth in scope—whether through stepwise progression or Cambrian explosion—of dominant technology platforms. Kissinger, Schmidt, and Huttenlocher forecast that the continuing development of AI will lead to a small number of international megafirms.[162] Suleyman forecasts that the coming technological wave will lead to the consolidation of economic power in the hands of a handful of "superstar" corporations with more scale and power than many nation-states.[163] The writing is on the wall for an economy characterized by many small, rivalrous producers.[164]

One may object that every great technological revolution since the rise of antitrust law in the late nineteenth century has spurred arguments that monopolistic scale is inevitable and competition doomed. The marginalist school of thought, which dominated economic thinking at the time of the Sherman Act's passage, insisted that competition was inconsistent with industries characterized by large, fixed costs and that either monopoly or collusion was inevitable.[165] The courts flatly rejected

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160 *See* Drexler, *supra* note 79, at 39–54 (describing how atomically precise manufacturing will shift value from physical resources to information and allow production "with negligible labor or resource cost").

161 *See* Manu Saadia, Trekonomics: The Economics of Star Trek 6 (2016).

162 *See* Kissinger, Schmidt & Huttenlocher, *supra* note 56, at 102–04.

163 Suleyman & Bhaskar, *supra* note 1, at 190–91.

164 The prediction that the coming wave will lead to extreme economic consolidation in a few megafirms does not necessarily imply *which* firms are likely to be the ones left standing. Eric Posner argues that the AI revolution will cement the monopoly of existing Big Tech firms. Eric A. Posner, *AI Revolution Likely to Cement Big Tech Monopoly*, Asset (Jan. 11, 2024), https://www.theasset.com/article/50713/ai-revolution-likely-to-cement-big-tech-monopoly [https://perma.cc/TYR3-DTZ9]. While that is plausible, I am not so sure that the existing distribution of AI capacity predicts which firms will be the survivors. Whatever firms do survive will surely be "Big Tech companies" in a literal sense, but the big point is that the coming wave will sweep most of production and distribution into a technology-driven system, even as to sectors of the economy that were not previously considered part of "tech." So Big Tech monopoly appears to be on the horizon far more than it is today, but not necessarily in the hands of Google, Facebook, Amazon, Apple, or Microsoft. To be very clear, this is not my wish—merely my prediction based on an analysis of technological trends.

165 Herbert Hovenkamp, The Opening of American Law: Neoclassical Legal Thought 1870–1970, at 208 (2015) ("In 1900 many economists and antitrust writers saw the 'ruinous

these "ruinous competition" arguments,[166] and subsequent developments in economic thinking eroded the marginalists' assumptions.[167] When similar arguments arose in the mid-twentieth century, the courts rejoined that economies of scale do not have to imply monopoly and that, even if there is some loss of efficiency to mandating smaller-scale production, that loss is an acceptable price to pay for living in a country in which economic power is dispersed. Perhaps the clearest such statement can be found in Learned Hand's *Alcoa* opinion, language that the Supreme Court subsequently endorsed[168]: "Throughout the history of these statutes it has been constantly assumed that one of their purposes was to perpetuate and preserve, for its own sake and *in spite of possible cost*, an organization of industry in small units which can effectively compete with each other."[169]

There are two problems with thinking that this position will continue to provide a bulwark against the concentrating effects of the coming wave. The first is one of practical capability. It is one thing to enjoin a firm or group of firms from colluding or merging, and quite another to countermand dominance that arises because technology makes a firm's output so vastly superior to its competitors'.[170] That would be much like telling an elephant to stop growing.

The second problem is that, even if it were feasible to suppress the inexorable growth of AI-driven firms, the social costs of doing that will become politically unsustainable. Just as consumers have downward-sloping demand curves for products and services, voters have downward-sloping demand curves for "an organization of industry in small units."[171] As the cost of an anti-concentration policy grows, its political sustainability erodes. The key difference between the market-concentrating effects of prior technological revolutions and that of the

competition' problem as so pervasive that either monopoly or collusion would be inevitable in many manufacturing markets.").

166 *See, e.g.*, Addyston Pipe & Steel Co. v. United States, 175 U.S. 211, 235 (1899) (rejecting the argument that a cartel agreement among cast-iron pipe producers was necessary to prevent ruinous competition); United States v. Joint-Traffic Ass'n, 171 U.S. 505, 576–77 (1898) (summarizing and rejecting defendants' ruinous competition argument); United States v. Trans-Missouri Freight Ass'n, 166 U.S. 290, 329–32 (1897) (same).

167 Hovenkamp, *supra* note 165, at 208–09.

168 United States v. Von's Grocery Co., 384 U.S. 270, 274 n.7 (1966); Brown Shoe Co. v. United States, 370 U.S. 294, 316 n.28 (1962).

169 United States v. Aluminum Co. of Am. (*Alcoa*), 148 F.2d 416, 429 (2d Cir. 1945) (emphasis added).

170 *See* John M. Yun, *Does Antitrust Have Digital Blind Spots?*, 72 S.C. L. Rev. 305, 323 (2020) ("What is the point of defining barriers to entry if welfare-enhancing activities like improving a product and making it more relevant for users now constitute a 'barrier to entry'?").

171 *Alcoa*, 148 F.2d at 429.

coming wave is the slope of the efficiency curve. The Second Industrial Revolution inevitably led to industrial consolidation and the elimination of many small- and medium-sized businesses,[172] but it did not have to imply monopoly because there were diminishing returns to scale at some relatively early point in the cost curve. Thus, first Standard Oil, and later AT&T, could be broken up either with no loss of efficiency (including increases in consumer prices, or degradation of quality or innovation) or a sufficiently small one given voter demand.[173] The coming wave's efficiency curve is likely to be very different. Even if an "organization of industry in small units"[174] could be mandated through force of law, the losses of efficiency—including such things as lifesaving medicines, vastly improved transportation systems, and dramatically lower prices for both necessities and luxuries—will make it politically infeasible for courts or regulators to insist on a small-producer economy "in spite of possible cost."[175]

D. Anticompetitive Conduct

The final pillar of the antitrust order that will buckle under the coming wave is the assumption that antitrust law is capable of preventing anticompetitive behavior. The first point to observe here is that AI's market-concentrating effects[176] will tend to make it either unnecessary or much easier for firms to engage in, or get away with, anticompetitive behavior. If a first mover in an AI-dominated market expands continuously in scale and scope, leaving potential competitors

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172 *See generally* Naomi R. Lamoreaux, The Great Merger Movement in American Business, 1895–1904 (1985) (discussing a major wave of industrial consolidations in U.S. manufacturing around the turn of the century that led to the disappearance of over 1,800 firms).

173 *See generally* Rory Van Loo, *In Defense of Breakups: Administering a "Radical" Remedy*, 105 Cornell L. Rev. 1955 (2020) (arguing that breakup remedies often entail no significant administrative difficulties or losses of efficiency).

174 *Alcoa*, 148 F.2d at 429.

175 An interesting predictive question concerns the expected longevity of the post-wave megafirms. Utilizing a sample consisting of publicly traded companies, Geoffrey West has shown that companies tend to follow inexorable power-law scaling that implies a half-life of about ten years, with almost one hundred percent expected company mortality (defined as bankruptcy or acquisition by another company) within fifty years. Geoffrey West, Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies 379–410 (2017). West attributes this morbid phenomenon to organic forces within companies that inevitably lead incumbent firms to narrow their product spaces and increasingly specialize. *Id.* at 409. Will post-wave megafirms follow the same pattern? To the extent that AI-driven systems will lead to extreme market concentration because the leading firms' underlying technology can be constantly deployed to new uses, the mechanisms described by West may no longer characterize post-wave companies.

176 *See supra* Section III.C.

in the dust, it does not need to rely on exclusionary behavior to become or remain a monopolist.[177] Or, if network effects and economies of scale result in a tight oligopoly with just a few firms, collusion among the firms becomes easier to undertake and more difficult to prove.[178] Thus, antitrust law's conduct rules, like its structure rules, will become either superfluous or much more difficult to enforce because of the structural changes precipitated by the coming wave.

Even apart from these structural changes, antitrust law's behavioral rules will become much more difficult, or eventually impossible, to enforce. In broad-brush terms, antitrust law's behavioral prohibitions fall into two categories (largely tracking sections 1 and 2 of the Sherman Act): collusion and exclusion. In the short run, AI and related technologies may have ambiguous effects on firms' ability to engage in those behaviors and on antitrust enforcers' ability to catch them. However, in the longer-run AI arms race between firms and enforcers, the firms have the decided advantage.

Start with collusion. In order for conventional human-to-human price fixing to work, cartelists must overcome a number of collective action problems, including coordinated output reduction and prevention of cheating or defection.[179] Existing AI technologies are already changing the nature of these problems, initially with ambiguous implications. AI-enabled improvements in demand forecasting may make initial collusion more feasible, but they may also increase the temptation to defection in periods of high predicted demand.[180] Conversely, while AI may facilitate cheating, it may also enable firms to better distinguish cheating from "unobserved negative demand shocks,"[181] which in turn enables the cartel to mete out more effective punishment.

Those effects suggest ambiguity in the consequences of AI and algorithmic pricing while these new technologies are aids to what is still human-driven decision-making on prices, agreements with competitors, and the punishment of defectors. But as pricing decisions are increasingly delegated to autonomous or semi-autonomous digital agents, the direction of the effects becomes less ambiguous: prices go up.

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177 *See* Daniel A. Crane, *Market Power Without Market Definition*, 90 NOTRE DAME L. REV. 31, 70–71 (2014) (explaining that when entry barriers are very high, incumbent firms have comparatively little incentive to engage in exclusionary conduct, since potential entrants have comparatively little prospect of entering the market and displacing incumbents).

178 Richard A. Posner, *The Chicago School of Antitrust Analysis*, 127 U. PA. L. REV. 925, 945 (1979) (observing that "concentration is a factor that facilitates collusion of a sort difficult to detect").

179 Michael K. Vaska, *Conscious Parallelism and Price Fixing: Defining the Boundary*, 52 U. CHI. L. REV. 508, 512 (1985).

180 Miklós-Thal & Tucker, *supra* note 52, at 13.

181 O'Connor & Wilson, *supra* note 52, at 3.

For example, economic theory predicts that the adoption of algorithmic price-setting technologies that allow for more frequent price changes and automated price changes in response to price changes by rivals can increase price levels.[182] As markets become more concentrated, which could occur due to mergers or the market-concentrating tendencies of the coming wave technologies discussed in Part II, upward pressures on prices intensify.[183] Similarly, the outsourcing of pricing decisions to third-party pricing algorithms tends to make prices more sensitive to demand variation and hence leads to higher prices.[184] These effects are no longer the consequences of cartel facilitation or stabilization. They are the consequences of a developing technology that permits firms to replicate cartel-like price structures without participating in a cartel.

Legally and analytically, there are two dimensions to the problem of algorithmic price-setting. One is whether the antitrust enforcement agencies can continue to detect price-fixing once machines take over key pricing decisions. Cartel detection is already a tall order. Scholars estimate that fewer than twenty percent of cartel agreements are detected, even in our pre-AI world.[185] Although antitrust enforcers can develop their own AI tools to enhance cartel detection,[186] they will inevitably be in an arms race with firms developing their own AI technologies to avoid being caught.[187]

The other, and more important, dimension is the substantive question of what counts as agreement—a necessary predicate to

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182 Brown & MacKay, *supra* note 52, at 1 (explaining that "[f]requency, commitment, and asymmetry in pricing technology allow firms to support higher prices in competitive . . . equilibrium").

183 *Id.*

184 *See generally* Harrington, *supra* note 52 (demonstrating that the outsourcing of pricing algorithms to third-party developers makes market prices more sensitive to demand variation).

185 *See* Emmanuel Combe, Constance Monnier & Renaud Legal, *Cartels: The Probability of Getting Caught in the European Union* 17 (Bruges Eur. Econ. Rsch., Paper No. 12, 2008), https://www.coleurope.eu/sites/default/files/research-paper/beer12.pdf [https://perma.cc/AV3A-5GE6]; Peter L. Ormosi, *A Tip of the Iceberg? The Probability of Catching Cartels*, 29 J. Applied Econ. 549, 549–50 (2014); John M. Connor, *Cartel Detection and Duration Worldwide*, Competition Pol'y Int'l: Antitrust Chron., Sept. 2011, at 4.

186 *See* Joseph E. Harrington, Jr. & David Imhof, *Cartel Screening and Machine Learning*, 2 Stan. Computational Antitrust 133, 135 (2022); Martin Huber & David Imhof, *Flagging Cartel Participants with Deep Learning Based on Convolutional Neural Networks*, 89 Int'l J. Indus. Org. 1, 16 (2023). *See generally* Thibault Schrepel & Teodora Groza, *The Adoption of Computational Antitrust by Agencies: 2nd Annual Report*, 3 Stan. Computational Antitrust 55 (2023) (reporting on efforts by twenty-six antitrust agencies to implement computational tools).

187 *See* Jason Furman & Robert Seamans, *AI and the Economy*, 19 Innovation Pol'y & Econ. 161, 177 (2019) (discussing AI's tendency to increase opacity and make collusion difficult to detect).

finding illegality under Section 1 of the Sherman Act[188] and most similar competition law regimes around the world.[189] The detection issue discussed in the previous paragraph assumes that there is some illegal behavior to catch. As AI and related technologies evolve from simply facilitating traditional cartel activity to replacing the need for explicit or implicit coordination among competitors on prices in order to achieve cartel-like price structures, it will be increasingly difficult for antitrust enforcers to make the case that the competitors have agreed to anything within the meaning of the antitrust laws. Ariel Ezrachi and Maurice Stucke have suggested four scenarios involving algorithmic collusion along a spectrum of increasing AI complexity.[190] The first two—a "messenger" scenario, where members of a cartel directly agree on an algorithm, and a "hub and spoke" scenario, where competitors separately outsource pricing decisions to a common algorithm—would likely be found to involve horizontal agreement under traditional antitrust principles.[191] A third "predictable agent" scenario, where each seller unilaterally creates its own algorithm knowing that it will likely facilitate parallel supracompetitive prices, could only be captured with a considerable stretch in current antitrust doctrines.[192] In the final scenario—a "digital eye" with a "God-like" view of the market—Ezrachi and Stucke argue that the "enforcement tool kit" may be empty, because no human being ever makes a price-setting decision.[193]

The digital eye is no longer a farfetched idea. Advances in AI technology are quickly pushing firms from a "participative decision-making" model, in which human agents rely on AI-enhanced algorithmic tools to improve their own decision-making, to wholesale delegations of pricing and related decisions to autonomous AIs.[194] The machine is not told to collude; it is told to maximize profits. Through reinforcement learning and "autonomous trial-and-error experimentation," the machine learns to replicate cartel prices.[195] Without any agreement

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188 *See, e.g.*, Bell Atl. Corp. v. Twombly, 550 U.S. 544, 553 (2007).

189 *See* Eleanor M. Fox & Daniel A. Crane, Global Issues in Antitrust and Competition Law 9–24 (2017).

190 Ezrachi & Stucke, *supra* note 85, at 36–37.

191 *Id.* at 39–55.

192 *Id.* at 56–70.

193 *Id.* at 71–81.

194 *See* Cindy Candrian & Anne Scherer, *Rise of Machines: Delegating Decisions to Autonomous AI*, 134 Comput. in Hum. Behav. 1, 2 (2022).

195 Timo Klein, *Autonomous Algorithmic Collusion: Q-Learning Under Sequential Pricing*, 52 RAND J. Econ. 538, 539 (2021). *See* Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò & Sergio Pastorello, *Artificial Intelligence, Algorithmic Pricing, and Collusion*, 110 Am. Econ. Rev. 3267, 3295 (2020) (finding that algorithms consistently learn to increase prices without communicating with each other).

with a competitor, either explicit or even tacit, autonomous algorithmic pricing can succeed in doing what generations of competitors in smoke-filled rooms could not.

One potential response to technology's leapfrogging of traditional antitrust doctrines would be to implement new antitrust doctrines. For example, Jonathan Baker has proposed a new definition of agreement for antitrust purposes in response to the challenges of algorithmic collusion.[196] Baker argues that:

> [C]ourts should presume that in an industry in which single-market cheating would likely be deterred by rapid price matching, and entry would not be expected to undermine a coordinated outcome, firms competing in multiple markets and setting prices by algorithm have reached an agreement on price for the purposes of enforcing Sherman Act § 1.[197]

Baker would then allow the defendants to rebut the prima facie showing with evidence that "their algorithms' pricing decisions respond to shifts in cost or demand consistent with what would be expected by firms engaged in one-time pricing interactions."[198] While this proposal might work as to relatively early generations of algorithmic price-setting technologies, it would likely become rapidly obsolete as developments in AI permit firms to delegate pricing power to digital agents with instructions to maximize the firm's profits but without instructions about *how* to do that. Here again we meet AI's black box problem. Imagine a firm that turns over its pricing decisions to a digital agent with the instruction simply to maximize the firm's long-run profits through a process of iterative machine learning. That is the same instruction that is effectively given to human managers. The difference is that AI has immensely more capability to determine profitable pricing strategies that avoid profit-reducing competitive equilibria. The AI's internal "logic"—the manner in which it arrived at its outcomes—will be opaque to courts and regulators, making it all but impossible to accuse the pricing system of anything other than having been given an improper objective function of maximizing profits. At that point, we clearly will have run far beyond the boundaries of antitrust law, which has never

196 *See* Jonathan B. Baker, The Antitrust Paradigm: Restoring a Competitive Economy 114 (2019) (arguing that two of the plus factors for finding agreement do not assist in the differentiation between sophisticated algorithms and leader-follower algorithms).

197 *Id.*

198 *Id.* at 114–15.

questioned the proposition that firms may aim to maximize their profits so long as the firm's managers do not behave anticompetitively.[199]

These observations as to the increasing difficulty of policing horizontal pricing decisions apply with equal force to the other principal branch of anticompetitive behavior—exclusionary strategies. As with collusion, the short-run effects of AI and related technologies may be to make traditional, human-directed exclusion strategies easier to implement, but with the offsetting potential for increases in counter-strategies by targeted competitors[200] and antitrust enforcers. Thus, Christopher Leslie has argued that algorithmic pricing undermines the traditional arguments that predatory pricing does not work as an exclusionary strategy, and that courts and enforcers should therefore update their prior beliefs about the likelihood that a dominant firm's pricing strategy is predatory.[201] But, as pricing decisions are increasingly delegated to digital agents with general profit-maximization instructions, it will be increasingly difficult for enforcers or courts to conclude that an AI's behavior is predatory. An AI does not have an "intention" to exclude competitors, nor would it have to directly consider the survival of competitors in making a pricing decision that would have the effect of excluding a competitor. For example, through machine learning, an AI might determine that when a new entrant shows up in the marketplace, the strategy that optimizes long-run profits is an immediate sharp price decrease. The AI does not even have to "know" that a new competitor has arrived to direct the price cut. It may simply be that when sales fall abruptly, the profit-maximizing solution is to cut prices aggressively. As with collusion, the ultimate answer to the question of why an AI set a particular price may be no more granular than "because that's what was shown to make the most money in the long run, as the system was programmed to do." In order to avoid being "predatory," the AI would have to be programmed to follow *unprofitable* strategies under some circumstances, for example by maintaining high prices upon competitive entry.[202] As with collusion, no existing antitrust principle requires firms to follow unprofitable strategies, and specifying such a rule would require nearly wholesale reinvention of antitrust law.

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199 *See, e.g.*, Barry Wright Corp. v. ITT Grinnell Corp., 724 F.2d 227, 234–35 (1st Cir. 1983) ("No one would condemn a price cut designed to maximize profits. . . .").

200 *See generally* Frank H. Easterbook, *Predatory Strategies and Counterstrategies*, 48 U. Chi. L. Rev. 263, 284–88 (1981) (arguing that victims of predatory strategies have available counter-strategies that may mitigate the effects of predation).

201 Christopher R. Leslie, *Predatory Pricing Algorithms*, 98 N.Y.U. L. Rev. 49, 53–54 (2023).

202 *See, e.g.*, Aaron S. Edlin, *Stopping Above-Cost Predatory Pricing*, 111 Yale L.J. 941, 946 (2002) (arguing for a rule that "if an entrant prices twenty percent below an incumbent monopoly, the incumbent's prices will be frozen for twelve to eighteen months").

Beyond the problem with attributing predatory behavior to a profit-maximization machine, the coming wave will present an even more fundamental problem for the policing of predatory pricing. Predatory pricing is defined as pricing by a firm below some "appropriate measure of its rival's cost,"[203] which is generally assumed to be some approximation of marginal, variable, or avoidable costs.[204] This already presents problems for antitrust enforcers in largely fixed-cost industries, where a firm may price very low without pricing below its marginal cost.[205] As the coming wave—particularly AI, robotics, energy expansion, and nanotechnology—increases economies of scale and scope and shifts economic value from atoms to bits,[206] cost structures across a wide swath of products and services will increasingly shift from variable to fixed. Not only will any but the largest firms find it difficult to remain profitable, but conventional predation analysis will find fewer and fewer candidates for condemnation. Antitrust law could respond by defining new cost standards including some consideration of fixed costs, but the existing problems of allocating joint and common costs across separate product lines[207] will be immeasurably more complex as to AI-driven production systems that draw on a common set of information costs to produce hundreds or thousands of separate products.

In combination, an AI's rote profit-maximization objective and the cost structure of its productive system will make it impossible to apply conventional predation analysis to an AI-driven system. Commercial conduct is only considered predatory if it is irrational or profit-decreasing "but for" the expectation that it will result in monopoly.[208] Cutting prices to above marginal cost levels in response to competitive

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203 Brooke Group Ltd. v. Brown & Williamson Tobacco Corp., 509 U.S. 209, 222 (1993).

204 Phillip E. Areeda & Herbert Hovenkamp, Antitrust Law: An Analysis of Antitrust Principles and Their Application ¶ 735b3 (2024).

205 *See, e.g.*, United States v. Microsoft Corp., 253 F.3d 34, 68 (D.C. Cir. 2001) (per curiam) (rejecting the Justice Department's predatory pricing theory).

206 *See supra* notes 158–62 and accompanying text.

207 *See, e.g.*, Louis Kaplow & Carl Shapiro, *Antitrust*, *in* 2 Handbook of Law and Economics 1073, 1087–88 (A. Mitchell Polinsky & Steven Shavell eds., 2007) (describing the difficulties in measuring marginal cost, especially with regard to identifying variable cost and allocating common cost); Franklin M. Fisher & John J. McGowan, *On the Misuse of Accounting Rates of Return to Infer Monopoly Profits*, 73 Am. Econ. Rev. 82, 82 (1983) (arguing that the accounting rate of return often used in monopoly analysis does not provide information regarding the economic rate of return); William J. Baumol, *On the Proper Cost Tests for Natural Monopoly in a Multiproduct Industry*, 67 Am. Econ. Rev. 809, 809 (1977) (finding that scale economies are neither necessary nor sufficient for the least costly form of output organization and that the focus should instead be on the subadditive cost function).

208 *See, e.g.*, Novell, Inc. v. Microsoft Corp., 731 F.3d 1064, 1075 (10th Cir. 2013) ("Put simply, the monopolist's conduct must be irrational but for its anticompetitive effect."); Viamedia,

pressures generally is not an irrational response absent exclusion.[209] Imagine that a firm sets up an automated ice cream vending machine next to a beach and programs its AI with the following instruction: Set prices dynamically to optimize profits, subject to the limitation that prices should never fall below marginal costs. Through computer vision and machine learning, the AI learns to optimize profits by adjusting prices based on a variety of factors (most of which a human vendor would never have determined to be relevant) such as changes in the consumer price index, weather conditions, the number of beachgoers, what kinds of bathing suits they are wearing, the kind of music they are playing, and whether other ice cream vendors are present on the beach. The other vendors learn that the AI will slash prices to just above marginal cost whenever they appear, and thus they stop selling at that beach. This is not predatory pricing in any conventional sense; the AI has been programmed to maximize profits, not to sacrifice them in the interests of exclusion. Its prices make economic sense as the rote application of a profit-maximization algorithm, and the processing steps that result in its prices are opaque. Given a world of vanishing marginal costs for large AI-driven firms, this example may soon be representative of competition (or its absence) in many markets.

The difficulties of preventing or catching predatory pricing after the coming wave will be equally true as to other exclusionary devices as well.[210] AI and machine learning-driven systems will work their ways to outcomes that eschew profit-depressing competition. Unlike human agents, the steps, strategies, and processes that underlie these outcomes will be opaque. Even assuming that it remains sensible to speak about AI and related technologies as having "exclusionary strategies" as opposed to the inexorable effect of consolidating economic power through the brute force of their internal logic, the conventional doctrines, tools, and techniques of antitrust law will be rendered largely obsolete by the economic changes implied by the coming wave.

Inc. v. Comcast Corp., 951 F.3d 429, 461 (7th Cir. 2020) (discussing the "no economic sense" test for predatory conduct).

[209] *See* Phillip Areeda & Donald F. Turner, *Predatory Pricing and Related Practices Under Section 2 of the Sherman Act*, 88 HARV. L. REV. 697, 701–02 (1975) (explaining that a firm maximizes profit by producing output when the marginal cost equals the market price).

[210] *See* Thomas K. Cheng & Julian Nowag, *Algorithmic Predation and Exclusion*, 25 U. PA. J. BUS. L. 41, 42–43 (2023) (discussing how algorithms permit dominant firms to target tying and bundling practices to loyal customers, thus reducing the reputational costs of those strategies and rendering them more effective).

IV
Three Potential Responses to the Coming Wave

The wave is coming, and it probably cannot be stopped, even if one wants to. This final Part briefly considers the responses available to the antitrust system in anticipation of the coming wave. They fall into three buckets. The first bucket consists of continuing to enforce antitrust principles more or less as usual. Although the coming wave is likely to render much of antitrust obsolete, it will not do so instantly, may not do so automatically, and probably will never do so completely, so some version of antitrust as competition policy is likely to continue for some time and in some spaces. As the wave crests and conventional economic competition dwindles, political pressure will likely mount to find replacements or surrogates for antitrust policy. A second bucket of responses, then, may consist of efforts to retain competition as an economic and legal principle, but relocating the locus of competition from between firms to within firms. Finally, a third bucket of responses may abandon actual competition as the organizing principle and instead attempt to recreate the historical functions of competition through direct regulation of an AI-driven system's objective functions.

A. Mandating Competition

Antitrust law and its institutional trappings may survive in some form for decades. Although the writing is on the wall for its long-term survival, four factors suggest that the antitrust order will continue for a generation or more.

1. Latency

A factor that will guarantee that antitrust will survive in something like its current form for a good while is the lag between the arrival of the coming wave's technologies and their widespread business implementation. Some of the technologies (AI, robotics, synthetic biology) have already arrived but are early in their development, while others (quantum computing and nanotechnology) are still years away in either experimental or practical deployment. Further, as noted earlier, there can be a lengthy period between a technology's commercial deployment for point solutions, which lead to limited efficiency gains but no overall change in business model, and system solutions, which revolutionize a business or industry.[211] So while the wave has already unleashed many currents that are challenging the antitrust order and

[211] *See supra* notes 63–66 and accompanying text.

will do so with increasing force over time, the system of antitrust as mandating market competition and prohibiting monopolistic structures and behaviors, can and should continue for the immediate future.

2. *Inertia*

Legal and regulatory systems often continue through the force of inertia long after their original justifications are gone.[212] The first two pillars of the antitrust order described above—information and incentives—relate to the comparative advantages of market competition over other forms of economic organization, which is to say that they are justifications for, not operational aspects of, the antitrust order. For these two pillars to collapse does not have to imply the immediate collapse of the antitrust order. Reform would require policymakers to recognize that the justifications for the status quo are gone and mandate new rules.

Further, while this Article has focused on the two leading economic premises concerning the comparative advantage of competitive markets and hence antitrust, there are many other potential arguments for mandating competitive markets. For example, competitive markets and antitrust may be important to reinforcing democracy,[213] diffusing social and economic power,[214] or cultivating a small-producer society for its own sake.[215] Given that the proper purposes of the antitrust laws remain varied and subject to debate,[216] the coming wave will not cause antitrust's collapse simply because AI systems generate vastly better information on consumer preferences and producer efficiencies and undermine traditional incentives arguments.

That said, the second two pillars—scale and scope and conduct control—*are* operational, and their demise will directly lead to antitrust's obsolescence. As AI-driven industries continue to tend toward a single dominant firm because of increasing economies of scale and scope and control of collusive and exclusionary conduct becomes

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212 *See, e.g.*, Seth P. Waxman, *The Physics of Persuasion: Arguing the New Deal*, 88 GEO. L.J. 2399, 2400 (2000) (examining how principles akin to physical laws, including inertia, explain legal outcomes).

213 *See* Daniel A. Crane, *Antitrust as an Instrument of Democracy*, 72 DUKE L.J. ONLINE 23, 23–24 (2022) (describing the political movement to ensure antitrust emphasizes democratic principles).

214 *See* Zephyr Teachout & Lina Khan, *Market Structure and Political Law: A Taxonomy of Power*, 9 DUKE J. CONST. L. & PUB. POL'Y 37, 37–39, 45 (2014) (emphasizing that the antitrust rules also shape economic and social power).

215 *See* United States v. Aluminum Co. of Am. (*Alcoa*), 148 F.2d 416, 429 (2d Cir. 1945) (describing the history of various antitrust statutes as intended to preserve small business concerns).

216 *See, e.g.*, Glick, Lozada & Bush, *supra* note 9.

possible in ever fewer cases, antitrust law will trend towards irrelevance. Further, as antitrust loses its ability to prevent monopolistic structures and anticompetitive prices, there will be renewed political interest in the question of why we have antitrust laws at all, which in turn will lead back to the diminishing advantages of competitive markets. All of this is to say that antitrust's purposes and its operations are ultimately intertwined, and the buckling of the four pillars is likely to bring down the whole house eventually.

3. Corporate Boundaries

One area of antitrust law—mergers[217]—may escape the effects of the coming wave longer than others. Agreements that modify the formal boundaries of the firm are not directly subject to AI's spontaneous or inevitable market-concentrating or competition-reducing effects. Two corporations that wish to merge must provide pre-merger notification to the antitrust agencies.[218] Then, the agencies and courts must decide whether to allow the merger to happen. Although the economic effects of the coming wave will surely be relevant to their analysis, the implications for merger policy in the near term remain uncertain. While AI-enhanced efficiencies might be invoked to justify certain mergers, the agencies and courts are more likely to view the market-concentrating tendencies of the coming wave as reasons to pull the only antitrust lever they realistically have left and say no to mergers. The upshot could be a period of years or decades in which markets are spontaneously concentrating and actions against anticompetitive conduct are diminishing, and merger law remains antitrust's last bastion.

Eventually, this too shall pass. Firms that can grow endlessly due to increasing economies of scale and scope do not need to merge to become dominant. Smaller competitors that cannot keep up with the efficiency of the market leaders or their AI-driven pricing and commercial strategies will exit the market. At the limit, antitrust law may be little more than a standing injunction against the combination through merger of the handful of remaining megafirms.

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[217] This observation includes merger-like joint ventures, which are evaluated under the same standards. *See* Fed. Trade Comm'n & U.S. Dep't of Just., Antitrust Guidelines for Collaborations Among Competitors § 1.3 (2000) (observing that "in some cases, competitor collaborations have competitive effects identical to those that would arise if the participants merged in whole or in part" and that the "[a]gencies treat [such] a competitor collaboration as a horizontal merger in a relevant market and analyze the collaboration pursuant" to ordinary merger analysis).

[218] 15 U.S.C. § 18a.

4. Anti-AI Markets

Antitrust may survive in remnant form as to the segment of the economy where, during and after the coming wave, there remains demand for the old way of life—the economic system that preceded the AI wave and, indeed, perhaps its predecessor waves like the Internet, computers, digitization, and industrialization. Although the stars are aligned for a revolutionary technological shift leading to a revolutionary economic shift, there is almost certain to be some residual demand for the horse and buggy. Rejecting AI, some consumers will demand services delivered only through human intelligence. Rejecting robotics, some consumers will demand handcrafted goods. Rejecting synthetic biology, some consumers will want their bodies, minds, foods, and goods left to nature. Rejecting nanotechnology, some consumers will only consume goods made from naturally occurring resources. And so there will continue to be markets driven by human intelligence and labor, information, and incentives, in which the old rules of competition will apply. Perhaps those markets will remain sufficiently important to the consumers and producers who frequent them, or at least to our historical and political consciousness, that it will remain worth our while as a society to run the antitrust system in its quaint little backwaters.

B. Simulating Competition Within the Firm

The coming wave will tend to consolidate economic power in a small number of firms,[219] with the consequence that traditional competition—competition among firms—will likely vanish or be driven to niche markets. When competition among firms dies, will it be possible to replace it with competition *within* firms? This would require defining modular units within monopoly organizations that draw on the common resources of the firm—the resources that created the firm's dominance—and then mandating that those modular units make commercial decisions separately from other modular units within the firm. Creating such a mandate might stimulate a kind of intra-firm competition that could produce beneficial results—low prices, high degrees of quality and innovation, and a diffusion of economic power—similar to those of traditional inter-firm competition.[220]

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[219] The ownership of those firms—whether they continue to be privately owned or socialized through some mechanism—is outside the scope of this article.

[220] *See* Nicolas Petit, *Innovation Competition, Unilateral Effects, and Merger Policy*, 82 ANTITRUST L.J. 873, 899 (2019) (explaining how intra-firm competition can have positive innovation effects); Steffen Ziss, *Hierarchies, Intra-firm Competition and Mergers*, 25 INT'L J. INDUS. ORG. 237, 237–38 (2007) (analyzing the potential for competition among separate units of a firm); Walter Adams, *The "Rule of Reason": Workable Competition or Workable*

From a legal and regulatory perspective, taking this approach would require abandoning a central tenet of antitrust law—that agreements among sub-units of the same corporate family don't count as agreement for purposes of the antitrust laws.[221] Contrary to present practice, it would require defining units within the firm that would be treated as formal modules expected to, and legally required to, make independent decisions from other modules.[222] For example, a conglomerated firm with monopoly positions in a number of separate products or services could be required to assign a separate and independent objective function to each product or service's controlling AI—to program the AI for each business unit to make decisions as though it were the firm's only business unit. Or, going a step further, a monopoly firm could be required to create separate virtual units within a single product or service and program an AI for each unit to assume itself in competition with the other units.

While the potential advantages of such an approach should be considered, it is not likely to be an appealing long-term solution. At a horizontal level, to the extent that AIs learn to engage in effective collusion with other firms,[223] creating artificial firms within the corporation would not eliminate monopoly pricing. At a vertical level, directing a series of vertically related monopolies to discount the net profitability of the parent firm in making pricing decisions over separate products could actually exacerbate monopoly pricing problems by inducing double marginalization—the successive monopoly markups that occur in a vertical chain of production and distribution subject to

Monopoly?, 63 YALE L.J. 348, 365 (1954) ("[E]ven in an industry which is completely monopolized there is still room for rather sharp *intra*-firm competition between the operating divisions of the monopoly.").

221 *See* Copperweld Corp. v. Independence Tube Corp., 467 U.S. 752, 777 (1984) (holding that a parent corporation and its wholly owned subsidiary are a "single entity" for the purposes of antitrust law and hence that intra-firm agreements are not agreements at all for the concerted action requirement of Section 1). The *Copperweld* doctrine has been applied more generally to cover Section 2 conspiracy claims of agreements among the firm and agents of the firm. *See, e.g.*, Las Vegas Sun, Inc. v. Adelson, No. 2:19-cv-01667-GMN-BNW, 2020 WL 7029148, at *9–10 (D. Nev. Nov. 30, 2020) (finding that the *Copperweld* doctrine applied to agents when they had no independent interest in the alleged conspiracy); Tonal Renal Care, Inc. v. W. Nephrology & Metabolic Bone Disease, P.C., No. 08–cv–00513–CMA–KMT, 2009 WL 2596493, at *13–14 (D. Colo. Aug. 21, 2009) (noting that a parent and its wholly-owned subsidiary cannot conspire under Section 2); Gucci v. Gucci Shops, Inc., 651 F. Supp. 194, 196 (S.D.N.Y. 1986) (explaining that "sister" corporations cannot conspire because they are analogous to a commonly owned corporation).

222 *See* Alan J. Meese, *Intrabrand Restraints and the Theory of the Firm*, 83 N.C. L. REV. 5, 8 (2004) ("[C]ooperation that takes place within a firm—what antitrust law calls 'unilateral conduct'—cannot inhibit competition that would otherwise occur, since all employees are by hypothesis already pursuing a common objective.").

223 *See supra* notes 176–99 and accompanying text.

market power.[224] To the extent that the goal of mandating intra-firm competition would be to diffuse economic power, it is not clear how that goal would be achieved either. Although commercial decisions might be decentralized to separate virtual actors within the firm, economic power would remain concentrated within the firm and not spread to others outside the firm's boundaries. From a social and political perspective, there is little to be gained by breaking a centralized monopolist into a set of commonly owned monopolists.[225]

C. Moving Beyond Competition

If the coming wave is likely to kill off competition as the economy's organizing force, then what shape will be assumed by antitrust's successor in law and regulatory policy? The trite answer is regulation, which has long been assumed to stand in as the surrogate for competition in natural monopolies.[226] Undoubtedly, in coming years, AI systems will be subject to increasing regulation along many dimensions, as they are already beginning to be.[227]

But what form of regulation will replace competition? Traditional natural monopoly regulation focused on three elements: (1) controlling the monopolist's prices through a "cost plus" formula that requires the regulated firm to submit its proposed prices for approval and allows rates no higher than costs plus a reasonable profit; (2) guaranteeing universal access and prohibiting discrimination; and (3) prohibiting the regulated firm from leveraging its power in the monopoly market to dominate adjacent competitive markets.[228] Only the second of these functions,

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224 *See* Joseph J. Spengler, *Vertical Integration and Antitrust Policy*, 58 J. Pol. Econ. 347, 349 (1950) (detailing the mathematics behind double marginalization).

225 Among economists, there is an old saying that the only thing worse than one monopolist is two monopolists.

226 *See* Richard A. Posner, Economic Analysis of Law 363 (6th ed. 2003) ("The law's traditional answer to the problem of natural monopoly was public utility or common carrier regulation."); Alfred E. Kahn, 2 The Economics of Regulation: Principles and Institutions 123 (1971) (describing regulation substituting for a natural monopoly through the example of the telephone market).

227 *See, e.g.*, *Blueprint for an AI Bill of Rights*, White House, https://www.whitehouse.gov/ostp/ai-bill-of-rights [https://perma.cc/XU6U-AE5T] (describing the federal government's principles to guide AI development); *Artificial Intelligence Act: Council and Parliament Strike a Deal on the First Rules for AI in the World*, Council of the Eur. Union (Feb. 2, 2024), https://www.consilium.europa.eu/en/press/press-releases/2023/12/09/artificial-intelligence-act-council-and-parliament-strike-a-deal-on-the-first-worldwide-rules-for-ai [https://perma.cc/P5LB-28H9] (announcing regulations and rules for AI in the European Union market).

228 *See generally* Jim Rossi & Morgan Ricks, *Foreword to Revisiting the Public Utility*, 35 Yale J. on Regul. 711, 711–12 (2018) (discussing traditional functions of public utility regulation); George L. Priest, *The Origins of Utility Regulation and the "Theories of Regulation" Debate*, 36 J.L. & Econ. 289, 294–95 (1993) (same); Henry C. Adams, *The*

to which much attention is already being paid,[229] makes much sense as applied to the coming wave's competition-eliminating tendencies. Conventional rate regulation was already challenging as to diversified entities that sold many different products drawing from a common cost pool, had relatively high fixed costs and low marginal costs, or sold both in regulated and unregulated markets.[230] All of these things will be true of the post-wave megafirms, which will make a conventional price regulation model very difficult. As to the traditional leveraging problem,[231] in the post-wave economy, expansion into adjacent markets will be an embedded feature of massively scalable AI-driven enterprises.[232] Strategic leveraging behavior of the kind employed by erstwhile regulated monopolists like AT&T[233] will not likely feature as a key regulatory concern. Regulation to prevent discriminatory behavior or other denials of universal service is likely to be part of the package of regulations focused on post-wave firms, but that will not address the tendency of a monopolist to maximize its profits by raising prices, reducing output, and degrading investments in quality and innovation.

The best candidate for a regulatory solution to this problem is harnessing the power of the AI system to regulate itself, subject to the public regulation of the AI's objective function.[234] Here, we return again to the observation in Section III.B about the significant way in which AI systems invert the characteristics of human managers, whose intentions are opaque but whose processing steps are discernible.[235]

Origins of Specific Economic Regulation and the Development of Regulatory Institutions, *in* Regulated Industries: Cases and Materials 1, 1–3 (2d ed. 1976) (same).

229 *See, e.g.*, Andrew D. Selbst & Solon Barocas, *Unfair Artificial Intelligence: How FTC Intervention Can Overcome the Limitations of Discrimination Law*, 171 U. Pa. L. Rev. 1023, 1025–26 (2023) (discussing the benefits of the FTC regulating discriminatory AI); Anya E.R. Prince & Daniel Schwarcz, *Proxy Discrimination in the Age of Artificial Intelligence and Big Data*, 105 Iowa L. Rev. 1257, 1260–61 (2020) (highlighting the risk of "proxy discrimination" in modern AI).

230 *See* Jordan J. Hillman & Ronald R. Braeutigam, Price Level Regulation for Diversified Public Utilities 2–3 (1989) (discussing issues with profit level regulation in the public utility market); David Boies, Jr., *Experiment in Mercantilism: Minimum Rate Regulation by the Interstate Commerce Commission*, 68 Colum. L. Rev. 599, 647 (1968) (discussing ICC rate regulation with allocation of joint and common costs).

231 *See generally* Louis Kaplow, *Extension of Monopoly Power Through Leverage*, 85 Colum. L. Rev. 515, 516–20 (1985) (examining the leveraging hypothesis and detailing the traditional leveraging approach).

232 *See supra* notes 151–57 and accompanying text.

233 *See* Paul L. Joskow & Roger G. Noll, *The Bell Doctrine: Applications in Telecommunications, Electricity, and Other Network Industries*, 51 Stan. L. Rev. 1249, 1249–50 (1999) (examining the AT&T divestiture under the Bell doctrine).

234 *See* Kai-Fu Lee & Chen Qiufan, AI 2041: Ten Visions for Our Future 30 (2021) (discussing regulation of an AI's objective functions to achieve socially desirable outcomes).

235 *See supra* notes 120–25 and accompanying text.

An AI's processing steps are opaque (the black box problem), but its intentions are precisely given by its objective function—the orders it is programmed to follow. In Section III.D, we assumed that AI programmers would thwart antitrust law's traditional prohibitions on collusion and exclusion by directing the AI to maximize profits without any strategic thought about competitors, at which point the AI would achieve that outcome without revealing any processing steps identifiable as collusive or exclusionary behavior.[236] But what if an AI were programmed to do something different than maximize the firm's profits: for example, to achieve the highest total social surplus, and then allocate the surplus among the firm, its customers, and its workers according to some predetermined formula? A monopoly firm would not be inclined to specify that objective function on its own initiative, but regulation might.

Regulation of this kind would not restore competition, but it would aim to achieve the same ends as competition historically achieved, without requiring the messiness and waste of competitive markets. And it would do so by drawing on a benefit-sharing concept that is already deployed in some antitrust systems. For example, under Article 101(3) of the Treaty on the Functioning of the European Union, an agreement that restricts competition can be justified when it "contributes to improving the production or distribution of goods or to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit."[237] Similarly, an AI might be directed to organize the firm's research and development, production, distribution, pricing, terms of service, and other attributes to maximize the well-being of specified categories of stakeholders (including profits for shareholders, wages or benefits for managers, wages or other terms of employment for employees, and low prices, high quality, innovation, and variety for customers), with specified criteria as to how surplus from the gains of trade should be allocated. Thus programmed, the AI might, for example, deploy automated processes to gather information on the costs of a particular medical condition and the benefits of a new treatment, invest firm resources in exploring a new pharmaceutical therapy, direct the production of the new drug, and then set its price and terms of distribution with an eye to sharing the surplus created between consumers and the firm.

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[236] *See supra* notes 172–206 and accompanying text.

[237] Consolidated Version of the Treaty on the Functioning of the European Union art. 101, Oct. 26, 2012, 2012 O.J. (C 326/56) 489. Article 101 contains further caveats, including that the restriction cannot eliminate "competition in respect of a substantial part of the products in question."

Needless to say, all of these decisions would be ones of great complexity, and one might wonder how a regulator could possibly be up to the task of supervising the AI's programming to achieve these socially optimal outcomes. Without minimizing the challenges ahead, below are four concluding thoughts on why this is nonetheless the likely path of post-wave, post-competition regulation.

First, there isn't much of a choice. For all of the reasons explored in this Article, the coming wave is likely to destroy the assumptions and practices on which markets have traditionally been predicated and regulated. Markets will concentrate, competition will dwindle, and there is relatively little that any state or government can do to stop it.[238] The big choices ahead are likely to be over ownership and regulation: who owns the megafirms (for example, do they become socialized and part of the state, or do they remain private or semi-private public utilities), and how should they be regulated? Whatever the ultimate ownership structures, the ultimate question will be what the AI that directs the deployment of resources and the fulfillment of human wants and needs is programmed to do. Someone will have to answer that question, and it seems unlikely that society will allow the answer to be given at the discretion of a handful of megafirm managers. Some democratically accountable oversight of the programmed instructions of an automated productive system affecting the lives of millions or billions of people seems desirable, and hopefully inevitable.

Second, a regulatory system that mandates some sharing of surplus rather than setting a firm's prices based on its costs would solve one of the longstanding problems with rate regulation: that the regulated firm, being guaranteed the same profit regardless of its effort, has little incentive to innovate or improve.[239] Traditional rate regulators did not have easily deployable tools to grant a regulated firm higher profits when the firm took actions like innovating that improved social welfare, but AI-driven systems may solve that problem by having far greater access to information about consumer needs and preferences and firm resources.[240]

Third, while there would be immense complexity involved in determining how to fulfill the objective function, that would be the AI's problem, not the regulator's. The regulator's task will be to understand what the AI is programmed to do and require any adjustments necessary

238 *See* Suleyman & Bhaskar, *supra* note 1, at 117–43 (arguing that the development of coming wave technologies is "unstoppable" due to a variety of overlapping factors).

239 *See* Phillip Areeda, *Essential Facilities: An Epithet in Need of Limiting Principles*, 58 Antitrust L.J. 841, 847–51 (1990) (discussing pivotal cases to demonstrate the ideas behind certain antitrust decisions to prevent limiting innovation).

240 *See supra* notes 86–99 and accompanying text.

to give the AI a more socially-minded mission. Further, that task would not need to be performed with standalone human intelligence—regulators will themselves need to rely on AI tools with comparable intelligence to those of the firms they regulate.

Finally, to say that a core regulatory function will be to supervise the programming of the AI's objective function is not to say that other kinds of regulatory supervision, whether automated or human, will not also be necessary or feasible. For example, the concept of "human-centered AI" (HCAI) focuses on deploying AI solutions that "amplify and augment rather than displace human abilities."[241] A regulatory HCAI approach might involve initial pre-clearance on the deployment of a dominant firm's new AI system to ensure the sociability of its objective function, followed by ongoing monitoring of the firm's behavior and outputs by both AI and human regulators to ensure consistency with social, democratic, or economic values.

Conclusion

This Article has made a series of bold and perhaps speculative predictions about a coming technological wave that may fundamentally disrupt the entire economic order on which antitrust law is based. Humility requires acknowledging that these trends may not come about in the way predicted by the sources on which this Article relies, or maybe even at all. There are also much darker possibilities than that the coming wave will destroy competitive markets and replace them with monopolies. The immense power of these technologies could be harnessed as weapons of mass destabilization and destruction, or even human extinction.[242] This Article has attempted to stake a position that is neither morbidly pessimistic nor Pollyannaish. It charts the most likely course given the current trajectory of these technologies' attributes and development, and works out their disruptive implications for the existing system of antitrust laws. The implications are radical, but, then again, so are the technologies.

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[241] Werner Geyer, Justin Weisz, Claudio Santos Pinhanez & Elizabeth Daly, *What Is Human-Centered AI?*, IBM: Blog (Mar. 31, 2022), https://research.ibm.com/blog/what-is-human-centered-ai [https://perma.cc/5YWV-JRHH] ("Human-Centered AI (HCAI) is an emerging discipline intent on creating AI systems that amplify and augment rather than displace human abilities. HCAI seeks to preserve human control in a way that ensures artificial intelligence meets our needs while also operating transparently, delivering equitable outcomes, and respecting privacy.").

[242] *See* Suleyman & Bhaskar, *supra* note 1, at 160–82 (discussing the potential for technologies of the coming wave to result in various cataclysmic outcomes, such as crippling cyberattacks, engineered pandemics causing mass destruction of human life, and disinformation campaigns leading to political collapses).

Returning to a point made in the introduction, law is about planning, and though the most dramatic of these changes may not come about for some time to come, it is not too early to begin planning for the effects of the coming wave. Technological and economic phenomena can be examined, legal and regulatory frameworks established, expectations leveled, habits of mind engrained, and new institutions designed and deployed before the current system is rendered obsolete. We can let the wave swamp us, but we would do better to ride it.