ALGORITHMS AS ILLEGAL AGREEMENTS

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ABSTRACT

Algorithms offer a legal way to overcome some of the obstacles to profit-boosting coordination, and create a jointly profitable status quo in the market. While current research has largely focused on the concerns raised by algorithmic-facilitated coordination, this Article takes the next step, asking to what extent current laws can be fitted to effectively deal with this phenomenon. To meet this challenge, this Article advances in three stages. The first Part analyzes the effects of algorithms on the ability of competitors to coordinate their conduct. While this issue has been addressed by other researchers, this Article seeks to contribute to the analysis by systematically charting the technological abilities of algorithms that may affect coordination in the digital ecosystem in which they operate. Special emphasis is placed on the fact that the algorithms is a "recipe for action," which can be directly or indirectly observed by competitors. The second Part explores the promises as well as the limits of market solutions. In particular, it considers the use of algorithms by consumers and off-the-grid transactions to counteract some of the effects of algorithmic-facilitated coordination by suppliers. The shortcomings of such market solutions lead to the third Part, which focuses on the ability of existing legal tools to deal effectively with algorithmic-facilitated coordination, while not harming the efficiencies they bring about. The analysis explores three interconnected questions that stand at the basis of designing a welfare-enhancing policy: What exactly do we wish to prohibit, and can we spell this out clearly for market participants? What types of conduct are captured under the existing antitrust laws? And is there justification for widening the regulatory net beyond its current prohibitions in light of the changing nature of the

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marketplace? In particular, the Article explores the application of the concepts of plus factors and facilitating practices to algorithms. The analysis refutes the claim that current laws are sufficient to deal with algorithmic-facilitated coordination.

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"We will not tolerate anticompetitive conduct, whether it occurs in a smoke-filled room or over the Internet using complex pricing algorithms . . . . Consumers have the right to a free and fair marketplace online, as well as in brick and mortar businesses."[1]

I. INTRODUCTION

Despite the increased transparency, connectivity, and search abilities that characterize the digital marketplace, the digital revolution has not always yielded the bargain prices that many consumers expected. Why not? Some researchers suggest that one factor may be coordination between the algorithms that are used by suppliers to determine trade terms.[2] Coordination-facilitating algorithms are already available off the shelf, and such coordination is only likely to become more commonplace in the near future. This is not

1. Press Release, U.S. Dep't of Just. Antitrust Div., Former E-Commerce Executive Charged with Price Fixing in the Antitrust Division's First Online Marketplace Prosecution (Apr. 6, 2015) (quoting Assistant Attorney General Bill Baer).

2. *See infra* Section II.B.

surprising. If algorithms offer a legal way to overcome obstacles to profit-boosting coordination, and to create a jointly profitable status quo in the market, it is no surprise that suppliers use them. In light of these developments, seeking solutions to algorithm-driven coordinated high prices—both regulatory and market-driven—is timely and essential. While current research has largely focused on the concerns raised by algorithmic-facilitated coordination, this Article takes the next step, asking to what extent current laws can be fitted to effectively deal with this phenomenon.

The use of algorithms in digital markets creates many benefits. Algorithms allow consumers to efficiently compare products and offers online, enabling them to enjoy lower-priced goods or find products that better fit their preferences.[3] Suppliers can quickly and efficiently analyze large amounts of data, allowing them to better respond to consumer demand, better allocate production and marketing resources, and save on human capital.[4] To achieve these results, algorithms perform a myriad of tasks, including collecting, sorting, organizing and analyzing data, making decisions based on that data, and even executing such decisions.

Some of these advantages are currently threatened by algorithmic-facilitated coordination among competitors.[5] Algorithms, some researchers

3. *See, e.g.*, Michal S. Gal & Niva Elkin-Koren, *Algorithmic Consumers*, 30 HARV. J.L. & TECH. 309, 318 (2017).

4. *See, e.g.*, Anthony Sills, *ROSS and Watson Tackle the law*, IBM (Jan. 14, 2016), https://www.ibm.com/blogs/watson/2016/01/ross-and-watson-tackle-the-law [https://perma.cc/GA65-FDQD] (virtual attorneys can read and sort through more than a billion of documents per second and have the capacity to learn the law and get smarter over time); Amir Khandani et al., *Consumer Credit-Risk Models Via Machine-Learning Algorithms*, 34 J. BANKING & FIN. 2767 (2010) (algorithms used to determine credit risks).

5. *See generally* ARIEL EZRACHI & MAURICE STUCKE, VIRTUAL COMPETITION (2016) (identifying four types of algorithmic conduct which can facilitate coordination); Salil K. Mehra, *Antitrust and the Robo-Seller: Competition in the Time of Algorithms*, 100 MINN. L. REV. 1323 (2016) (identifying the traits of algorithms which lead to coordination); Bruno Salcedo, Pricing Algorithms and Tacit Collusion 3 (Nov. 1, 2015) (unpublished manuscript) (on file with author) ("[W]hen firms compete via algorithms that are fixed in the short run but can be revised over time, collusion is not only possible but rather, it is *inevitable*." His results hold under specific assumptions regarding market conditions such as demand shocks that are more frequent than algorithm revisions.); *see generally* ORG. FOR ECON. CO-OPERATION & DEV., ALGORITHMS AND COLLUSION: COMPETITION POLICY IN THE DIGITAL AGE, 11–12 (2017) [hereinafter OECD]. For a more cautious view, see, e.g., Ulrich Schwalbe, Algorithms, Machine Learning, and Tacit Collusion 16 (Apr. 5, 2018) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3232631 [https://perma.cc/L3ZN-HEU7] ("[C]oordinated behaviour of algorithms is a possible outcome, but it is not as quick and easy or even unavoidable as it is often assumed."); Ashwin Ittoo & Nicolas Petit, Algorithmic Pricing Agents and Tacit Collusion: A Technological Perspective (Oct. 12, 2017)

argue, make coordination among suppliers easier and quicker than ever before. The higher levels of interconnection and transparency in digital markets, combined with more available data and a higher level of sophistication of analysis, makes reaching a joint profit-maximizing equilibrium easier. The speed and ease of detection and response to deviations from the coordinated equilibrium reduces incentives to break ranks. Joseph Harrington, Professor of Business Economics and Public Policy at Wharton Business School, argues that given developments in algorithmic agents, "the emergence of [coordination] . . . in actual market settings would seem extremely possible in the near future, if it is not already occurring."[6] Ariel Ezrachi and Maurice Stucke, Professors of Law at Oxford and the University of Tennessee, respectively, suggest in their seminal work on virtual competition that this effect is so strong, it marks the end of competition as we know it.[7]

Should algorithms indeed facilitate coordination in markets otherwise not prone to it, market participants and regulators need to explore what tools, if any, can be used to reduce the negative welfare effects of algorithmic-facilitated coordination on both consumer and social welfare.[8] While previous work suggested a (partial) market solution,[9] this Article focuses on legal remedies. In particular, this Article explores whether by applying laws that were designed to regulate human-facilitated market coordination we are limiting ourselves to looking only under the proverbial lamppost, while the activities we are interested in take place in the dark. If so, can we address this problem by using a stronger light bulb (i.e., widening the scope of existing laws by way of interpretation)? Or do we need to create a new source of light altogether (i.e., new laws)? Indeed, algorithms challenge the assumptions on which antitrust law is currently based. To illustrate, algorithms, unlike humans, can "read the minds" of other algorithms even before they perform any action, thereby transforming the need for an explicit commitment to coordinate or to

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(unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3046405 [https://perma.cc/D6YV-J98R]. Coordination is not always welfare-reducing.

6. Joseph E. Harrington Jr., Developing Competition Law for Collusion by Autonomous Price-Setting Agents 6 (Aug. 22, 2017) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3037818 [https://perma.cc/D8UP-Q7PM].

7. *See* EZRACHI & STUCKE*, supra* note 5; *see also* LORDS SELECT COMMITTEE ON EUROPEAN UNION, ONLINE PLATFORMS AND THE DIGITAL SINGLE MARKET, REPORT, 2016-4, HL 129, ¶¶ 178–79 (UK) (acknowledging the rise of potential new means of collusion).

8. For a short exposition, see Michal S. Gal, *Algorithmic-Facilitated Co-ordination: Market and Legal Solutions*, 1 COMPETITION POL'Y INT'L (2017).

9. *See* Gal & Elkin-Koren, *supra* note 3, at 325–34.

punish deviations.[10] This new reality requires us to rethink concepts that stand at the basis of our laws, like the meeting of minds, intent, consent, and communication, and possibly requires us to create a new taxonomy to fit the algorithmic world. The analysis is timely: competition authorities all over the world are starting to explore such issues in depth, and the legality of algorithmic-facilitated coordination is likely to become a major issue, given rapid advancements in machine learning.

To meet this challenge, this Article advances in three interconnected stages (Part II–IV). Part II analyzes the effects of algorithms on the ability of competitors to coordinate their conduct. While this issue has been addressed by other researchers,[11] this Part of the Article seeks to contribute to the analysis by systematically charting the technological abilities of algorithms that may affect coordination in the digital ecosystem in which they operate. Part III explores the promises as well as the limits of market solutions. In particular, this Part considers the use of algorithms by consumers and off-the-grid transactions to counteract some of the effects of algorithmic-facilitated coordination by suppliers. The shortcomings of such market solutions lead to Part IV, which focuses on the ability of existing legal tools to deal effectively with algorithmic-facilitated coordination, while not harming the efficiencies they bring about. Further, this Article explores three interconnected questions that stand at the basis of designing a social welfare-enhancing policy: What exactly do we wish to prohibit, and can we spell this out clearly for market participants? What types of conduct are captured under the existing antitrust laws, thereby treating coordination-facilitating algorithms as illegal agreements? And is there justification for widening the regulatory net beyond its current prohibitions in light of the changing nature of the marketplace? The analysis refutes the Federal Trade Commission's acting Chairwoman's claim that current laws are sufficient to deal with algorithmic-facilitated coordination.[12]

10. *See* John von Neumann, *First draft of a report on the EDVAC*, *in* 15 IEEE ANNALS HIST. COMPUTING 27, 33–34 (1993).

11. Most notably by EZRACHI & STUCKE, *supra* note 5.

12. Maureen K. Ohlhausen, Comm'r, Fed. Trade Comm'n, Remarks from the Concurrences Antitrust in the Financial Sector Conference: Should We Fear The Things That Go Beep in the Night? Some Initial Thoughts on the Intersection of Antitrust Law and Algorithmic Pricing (May 23, 2017) ("From an antitrust perspective, the expanding use of algorithms raises familiar issues that are well within the existing canon.").

II. ALGORITHMS AS COORDINATION FACILITATORS

Coordination among competitors is generally welfare-reducing: it lowers competitive pressures at the expense of price and choice.[13] Accordingly, the increased use of algorithms in the marketplace requires us to determine whether and to what extent algorithms facilitate coordination. To answer this, this Part first explores the conditions that must exist for coordination to take place; and then analyzes the ways that algorithms affect these conditions. As will be argued, while algorithms cannot facilitate coordination in all market settings, they can do so in a subset of markets, in which their characteristics enable competitors to overcome existing obstacles to coordination.

A. THE ECONOMICS OF COORDINATION

Competitors may have incentives to coordinate their conduct instead of competing among themselves. Nobel laureate economist, George Stigler, identified three cumulative conditions that must exist for such coordination to take place:[14]

1. *Reaching an understanding (or agreement)* on what trade conditions (e.g., price, quantity, or quality) will be profitable for all parties to the agreement. This means both resolving any disagreements as to the "correct" trade terms that all parties perceive as beneficial relative to a situation in which they do not coordinate, and communicating the ultimate decision to all parties.
2. *Detection of deviations* from the supra-competitive equilibrium. The slower and less completely deviations are detected, the weaker the coordination, as firms have stronger incentives to cheat. Also, if market conditions are not conducive to exposing deviations, firms seeking to detect deviations incur substantial costs. This reduces the overall attractiveness of coordination.
3. Creating a *credible threat of retaliation* in order to discourage deviations.

Economic theory further recognizes a fourth condition that must exist for coordination to take place:[15] *high entry barriers* in the market in which the

13. *See, e.g.*, 11 PHILLIP E. AREEDA & HERBERT HOVENKAMP, ANTITRUST LAW: AN ANALYSIS OF ANTITRUST PRINCIPLES AND THEIR APPLICATION (1980) (suggesting exceptions exist when coordination is necessary to increase competition or efficiency).

14. George J. Stigler, *Theory of Oligopoly*, 72 J. POLITICAL ECON. 44, 44–46 (1964).

15. *See generally* ROBERT C. MARSHALL & LESLIE M. MARX, THE ECONOMICS OF COLLUSION (2012); Edward J. Green et al., *Tacit Collusion in Oligopoly*, *in* 2 OXFORD HANDBOOK OF INT'L ANTITRUST ECON. 464 (Roger D. Blair & D. Daniel Sokol eds., 2015). High entry barriers exist where the costs of new entry into a market are high.

coordinating parties operate. With low entry barriers, new competitors can easily enter and sweep the market, thereby reducing incentives to set supra-competitive trade terms in the first place.[16]

Economics and jurisprudence differ in their interpretations of Stigler's first condition: what constitutes reaching an agreement. In economic parlance, reaching an agreement captures both explicit agreements and conscious parallelism.[17] The former refers to cases where the parties exchange mutual assurances prior to their actions to act in a coordinated manner.[18] The latter, sometimes called oligopolistic coordination or tacit collusion, occurs when firms independently set their trade terms while taking into account their competitors' probable reactions to their actions.[19] In economic models, especially game theoretic ones, the specific method used to reach the agreement is not important.[20] However, as elaborated below, antitrust law is largely based on the distinction between these two situations. Only the former is considered to constitute "agreements" in the legal sense and is, therefore, potentially illegal; instances of conscious parallelism are not.[21]

The economics literature which deals with coordination among market players focuses on the market settings that must exist for Stigler's conditions to be fulfilled. As has been shown, even highly concentrated markets—in which only a small number of market players operate—can produce an uncertain market equilibrium, ranging from supra-competitive conditions, in which the trade terms offered to consumers are much less beneficial than under competitive conditions, to competitive ones.[22] Yet it is widely agreed that some market conditions and types of actions can make supra-competitive trade terms more likely, especially in a repeated market game.[23]

The economics literature identifies five broad categories of variables that affect Stigler's conditions: (1) market structure variables (e.g., market concentration, entry barriers), (2) product variables (e.g., product and cost homogeneity, multiplicity of products), (3) sales variables (e.g., secrecy), (4) demand variables (e.g., demand fluctuations, difficulties in estimating demand

16. *See* MARSHALL & MARX, *supra* note 15.

17. *See, e.g.*, William H. Page, *Tacit Agreement Under Section 1 of the Sherman Act*, 81 ANTITRUST L.J. 593, 593–94 (2017) (also noting that these terms have not been used consistently in case law or scholarly writings).

18. *Id.* at 619.

19. *Id.* at 601.

20. *See* LOUIS KAPLOW, COMPETITION POLICY AND PRICE FIXING 8 (2013).

21. *See* Page, *supra* note 17, at 602.

22. JEAN TIROLE, THE THEORY OF INDUSTRIAL ORGANIZATION (1988).

23. *See, e.g.*, Gregory J. Werden, *Economic Evidence on the Existence of Collusion: Reconciling Antitrust Law with Oligopoly Theory*, 71 ANTITRUST L.J. 719, 729–30 (2004).

for new products), and (5) the "personality" of the firms operating in the market (e.g., a tendency to act as a maverick).[24] The relevant factors may vary within a market over time, and some, such as entrepreneurial attitudes towards engagement in illegal activity, are intrinsically variable. Moreover, none of the factors are deterministic in their ability to facilitate coordination. Rather, they all reflect general tendencies subject to random deviations. In reality, a combination of market conditions will determine the likelihood of coordination. In what follows, I discuss some of the main coordination-facilitating factors.[25]

A concentrated market structure, where a small number of competitors are protected by high entry barriers, is a condition strongly conducive to coordination. This is because reaching an agreement to limit competition is easier and less costly if the number of firms involved is small.[26] With fewer firms to be checked for deviating conduct, detection of cheating is also easier. Furthermore, "[a] large number of firms not only makes it harder to identify a 'focal point' for co-ordination, but it also reduces the incentives for collusion as each player would receive a smaller share of the supra-competitive gains that an explicit or tacit collusive arrangement would be able to extract."[27]

Indeed, the number of firms is so important that it is largely assumed that conscious parallelism can only be reached in oligopoly markets (hence its alternative name, "oligopolistic coordination"). An oligopoly exists when a small number of firms dominate the market.[28] The main economic characteristic of oligopolistic markets is that each firm's decisions have a noticeable impact on the market and on its competitors.[29] Though each firm may strategize independently, any rational decision must take into account the anticipated reaction to its decisions by competitor firms.[30] The decisions of firms in an oligopoly may thus be interdependent even though arrived at independently. Such mutual interdependence may forestall competitive conduct.

Transparency of transactions makes it easier to coordinate market offers, to detect deviations, and to determine the level of sanctions that should be

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24. *See, e.g.*, TIROLE, *supra* note 22.

25. *See, e.g.*, MARC IVALDI, BRUNO JULLIEN, PATRICK REY, PAUL SEABRIGHT & JEAN TIROLE, THE ECONOMICS OF TACIT COLLUSION 11 (2003); *see generally* SIGRID STROUX, US AND EC OLIGOPOLY CONTROL (2004).

26. IVALDI ET AL., *supra* note 25, at 12.

27. OECD, *supra* note 5, at 20–21.

28. Carl Shapiro, *Theories of Oligopoly Behavior*, *in* HANDBOOK OF INDUSTRIAL ORGANIZATION 329 (R. Schmalensee & R.D. Willig eds., 1st ed. 1989).

29. *Id.*

30. *Id.*

applied to deviators.[31] Furthermore, transparency in any firm's decisional parameters and in the inputs used in the decision making process make it simpler for others to understand what is driving their competitors' actions.[32] As a result, this makes it easier to reach an agreement and limits the instances in which a mistaken categorization of a competitor's actions could lead to a price war.[33]

The availability of information also affects coordination: the noisier or more incomplete the information, the harder it is to coordinate.[34] Along those lines, demand fluctuations make it more difficult to set a stable, jointly profitable price. They also make detection of deviations much harder and increase the chance of a price war.[35] Consider the following example: a supplier observes that demand for his product is reduced. He cannot effectively differentiate between natural changes in consumer demand, which are likely to affect all suppliers in the market (or even mainly his product if products are heterogeneous), and deviation from the status quo on the part of a competing supplier who now enjoys a larger market share. Both possibilities may lead the supplier to lower his prices, potentially triggering a price war. It may take time until coordination is once again achieved, if at all. Accordingly, the more imperfect the price signals among suppliers, the less stable the coordination.

Economic studies have also shown that pre-play communication among suppliers is important for coordination.[36] Indeed, experiments on oligopolies have shown that absent communication, tacit collusion is not easy to achieve.[37] Cooper and Kuhn show that explicit threats to punish cheating are the most important factor in successfully establishing coordination, once a cooperative strategy is established.[38]

Where market conditions create obstacles to coordination, firms may take more direct actions that facilitate coordination (or purposefully refrain from certain actions that limit it). Such actions include behavior that helps firms

31. IVALDI ET AL., *supra* note 25, at 25.

32. *Id.* at 26.

33. *Id.* at 25–26.

34. *See* Schwalbe, *supra* note 5, at 12.

35. Edward J. Green & Robert H. Porter, *Noncooperative Collusion under Imperfect Price Information*, 52 ECONOMETRICA 87, 94–95 (1984).

36. *See, e.g.*, Joseph E. Harrington, Jr., *How do Cartels Operate?*, 2 FOUND. & TRENDS IN MICROECONOMICS 1 (2006); Yu Awaya & Vijay Krishna, *On Communication and Collusion*, 106 AM. ECON. REV. 285 (2015).

37. *See, e.g.*, Jan Potters & Sigrid Suetens, *Oligopoly Experiments in the Current Millennium*, 27 J. ECON. SURVEYS 439 (2013); Niklas Horstmann, Jan Krämer, & Daniel Schnurr, *Number Effects and Tacit Collusion in Experimental Oligopolies*, J. INDUS. ECON. (forthcoming).

38. David J. Cooper & Kai-Uwe Kühn, *Communication, Renegotiation, and the Scope for Collusion*, 6 AM. ECON. J. MICROECONOMICS 247, 268 (2014).

overcome the complicating factors that make coordination infeasible or insufficient to yield monopoly profits.[39] Such practices may range widely, from standardizing products or notifying competitors of upcoming changes in prices, to signaling how one will react to market changes.[40] They can be adopted either by agreement or unilaterally.[41] Accordingly, both the market's natural conditions, as well as actions taken by market players, affect the ability to meet Stigler's three conditions for coordination.

B. How Algorithms Facilitate Coordination

Can algorithms affect the market equilibrium and facilitate coordination? To answer this question, we need to explore how algorithms may affect the conditions for coordination explored above.

Addressing this issue requires us to combine insights from computer science and economics. Computer science brings light on the technological side as to how algorithms operate, and their comparative advantages and limitations. Economics brings light on the market equilibria that will most likely ensue, given the market conditions created by algorithms. Below, I briefly explore insights from both disciplines. I start by briefly reviewing the characteristics of algorithms, and then relating them to the ability to facilitate coordination.

1. *What Are Algorithms?*

Algorithms are structured decision-making processes that automate computational procedures to generate decisional outcomes on the basis of data inputs.[42] In a broad sense, we all use (non-automated) algorithms in our daily lives. For example, when we decide what to wear, we use data inputs (such as the weather, the occasion, and comfort) and weigh them in order to reach an outcome that most accords with our preferences (e.g., one cannot wear a comfortable jumpsuit to a formal party). Coded algorithms do the same. They use predetermined decision procedures in order to suggest a decision, given particular data.[43]

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39. *See* George A. Hay (1984), *Facilitating Practices: The Ethyl Case*, *in* THE ANTITRUST REVOLUTION: ECONOMICS, COMPETITION, AND POLICY 182, 189 (Kwoka & White eds., 3rd ed. 1999).

40. *See, e.g.*, Steven C. Salop, *Practices that (Credibly) Facilitate Oligopoly Coordination*, *in* NEW DEVELOPMENTS IN THE ANALYSIS OF MARKET STRUCTURE 265, 271 (Joseph E. Stiglitz & G. Frank Mathewson eds., 1986); William H. Page, *Facilitating Practices and Concerted Action under Section 1 of the Sherman Act*, *in* ANTITRUST LAW AND ECONOMICS 23 (Hylton ed., 2010).

41. *See* Salop, *supra* note 40.

42. *See* THOMAS H. CORMEN, CHARLES E. LEISERSON, RONALD L. RIVEST & CLIFFORD STEIN, INTRODUCTION TO ALGORITHMS 5 (3rd ed. 2009).

43. *Id.* at 192–93, 843–49.

Algorithms vary significantly in the computational procedures they use (such as sorting or merging data, finding correlations, etc.) and their efficiency in achieving the given task (including time, amount of data, and computer power needed to complete a task).[44] Importantly for our analysis, algorithms can operate at different levels of abstraction. At the lowest level, all parameters are dictated by the developer in advance ("expert algorithms").[45] Such pre-selection of relevant features enables the algorithm to operate more quickly, and also reduces the amount of data needed.[46] Yet such pre-selection is rigid in the sense that if correlations in the data change over time, the algorithmic decision will not reflect this. Accordingly, algorithms can be designed to set or to refine their own decision parameters in accordance with the data inputted in them and the decision-making techniques they are coded to perform ("learning algorithms").[47] Learning algorithms employ machine learning—a type of artificial intelligence that gives computers the ability to learn from the data they encounter without the need to define correlations a priori.[48] Accordingly, learning algorithms do not follow strictly static program instructions, but rather build a decision process by learning from data inputs. Machine learning is employed in a range of computing tasks where designing and programming explicit algorithms with good performance is difficult or unfeasible (common examples include spam filtering and optical character recognition).[49] While machine learning identifies correlations between data inputs, it usually does not explain the causality of such correlations.[50] Some algorithms combine the functions of expert and learning algorithms.[51]

In today's world, characterized by big data, fast digital connectivity, and increased computational and storage capacity, algorithms may create significant advantages in decision-making. The most basic advantage they offer

44. *Id.* at 5–6.

45. OECD, *supra* note 5, at 11–12.

46. *See* Yann LeCun, Yoshua Bengio & Geoffrey Hinton, *Deep Learning*, 521 NATURE 436, 436 (2015).

47. *See, e.g.*, OECD, *supra* note 5, at 9–11. For examples of machine learning already used in algorithms, see Ariel Ezrachi & Maurice E. Stucke, *Artificial Intelligence & Collusion: When Computers Inhibit Competition*, 2017 U. ILL. L. REV. 1775 (2017).

48. *See generally* TOM MITCHELL, MACHINE LEARNING (1997). Other types of artificial intelligence include, for example, expert systems, which use databases of expert knowledge, to offer advice on make decisions in such as areas as medical diagnosis of stock exchange trading.

49. OECD, *supra* note 5, at 11–13.

50. Some advanced algorithms can also find causality. *See, e.g.*, Rainer Opgen-Rhein & Korbinian Strimmer, *From Correlation to Causation Networks: A Simple Approximate Learning Algorithm and Its Application to High-Dimensional Plant Gene Expression Data*, 1 BMC SYSTEMS BIOLOGY 37 (2007).

51. Schwalbe, *supra* note 5, at 15.

is speed in the collection, organization, and analysis of data, enabling exponentially quicker decisions and reactions.[52] The vast volume of data now available, which challenges the human cognitive capacity to process the relevant information, has made this ability even more important.[53] Given any number of decisional parameters and data sources, computers can generally apply the relevant algorithm at a velocity unreachable by the human brain, especially if the decision involves a large number of parameters that need to be balanced or many data inputs that must be analyzed or compared.[54] Automatic acceptance of the algorithm's suggestion further enables an exponentially quicker reaction. As innovator Elon Musk observed, "[a] computer can communicate at a trillion bits per second, but your thumb can maybe do . . . 10 bits per second or 100 if you're being generous."[55]

The second main advantage of algorithms relates to their analytical sophistication. Advances in data science, including data collection and storage, have ushered in the age of big data, which enables algorithms to integrate numerous variables into their decisions.[56] This provides a level of sophistication that cannot be achieved by the human mind without substantial time and effort. In one noteworthy example, algorithms defeated world champions in the strategic game Go.[57]

It is thus not surprising that the use of algorithms to make commercial decisions is spreading fast. Algorithms are used in a myriad of tasks, including responding rapidly to changes in demand conditions, determining efficient levels and locations for production and storage, and assessing risk levels.[58] Important for our analysis, they are also used for pricing decisions.[59] Some common examples include Uber's surge pricing algorithm, which is used to set

52. *See, e.g.*, OECD, *supra* note 5, at 15; Harrington, *supra* note 6, at 54. For an example, see the velocity of facial recognition though an algorithm: PATRICK GROTHER, MEI NGAN, & KAYEE HANAOKA, ONGOING FACE RECOGNITION VENDOR TEST (FRVT) (2018).

53. For the importance of data, see, e.g., Avigdor Gal, It's a Feature, Not a Bug: On Learning Algorithms and What They Teach Us (unpublished Note for the 127th meeting of OECD Roundtable on Algorithms and Collusion 21–23 June 2017).

54. Harrington, *supra* note 6.

55. Steve Renick, *Elon Musk at the World Government Summit 2017 in Dubai. Conversation with Mohammad AlGerga*, YOUTUBE (June 22, 2017), https://www.youtube.com/watch?v=R5dHlLjOdjk [https://perma.cc/G4RQ-SJJN].

56. *See, e.g.*, Matthew Adam Bruckner, *The Promise and Perils of Algorithmic Lenders' Use of Big Data*, 93 CHI.-KENT L. REV. 3 (2018).

57. *See* Paul Mozur, *Google's AlphaGo Defeats Chinese Go Master in Win for A.I.*, N. Y. TIMES (May 23, 2017), https://www.nytimes.com/2017/05/23/business/google-deepmind-alphago-go-champion-defeat.html [https://perma.cc/S8FU-4PPQ].

58. *See generally* OECD, *supra* note 5; Rob Kitchin, *Thinking Critically About and Researching Algorithms*, 20 INFO., COMMC'N & SOC'Y 14 (2017).

59. *See* OECD, *supra* note 5, at 16; *see also* Ezrachi & Stucke, *supra* note 5.

prices based on demand and supply conditions, and the algorithm used by Airbnb to price differentiated offers.[60] In parallel to the creation of tailor-made algorithms, software firms also sell off-the-shelf pricing algorithms, which can be relatively easily fit to each supplier's needs.[61] Some examples include Feedvisor's self-learning algorithmic repricer, which uses artificial intelligence and big data techniques to set prices,[62] or Inoptimizer, a pricing engine based on artificial intelligence and data on competitors' and consumers' behavior.[63] Sophisticated algorithms often treat pricing as a reinforcement learning issue, changing their decision matrix in an ongoing way as they learn from market interactions.[64]

Algorithms can also be used to learn how other business entities set their trade conditions. They can do this by directly observing and analyzing the code of other algorithms, or by analyzing competitors' behavior under given market conditions to indirectly learn their decisional parameters.[65] Algorithms can also police other firms, by determining when another firm has strayed from the status quo and by setting trade conditions designed to deter firms from doing so.[66]

The ability of algorithms to achieve their function is contingent on several factors. The first is the quality and volume of the data used by the algorithm as inputs. The best theoretical model will only work well if it has the necessary information on which to base its decisions.[67] Accordingly, the ability of firms to access data which is necessary in order to determine the coordinated outcome affects their ability to coordinate. Data can come from many sources, including the Internet, sensors placed in physical goods ("Internet of Things"),

60. *See, e.g.*, Ryan Calo & Alex Rosenblat, *The Taking Economy: Uber, Information, and Power*, 117 COLUM. L. REV. 1623, 1656 (2017); Kenneth A. Bamberger & Orly Lobel, *Platform Market Power*, 32 BERKELEY TECH. L.J. 1051, 1071 (2017); Shagun Jhaver, Yoni Karpfen & Judd Antin, *Algorithmic Anxiety and Coping Strategies of Airbnb Hosts*, *in* PROCEEDINGS OF THE 2018 CHI CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS (2018).

61. *See, e.g.*, OXERA, WHEN ALGORITHMS SET PRICES: WINNERS AND LOSERS (2017).

62. *Amazon Algorithmic Repricer*, FEEDVISOR, https://feedvisor.com/amazon-repricer/ [https://perma.cc/T4VV-7KB9] (last visited Mar. 18, 2019).

63. *Inoptimizer*, INTELLIGENCE NODE, http://www.intelligencenode.com/products-inoptimizer.php [https://perma.cc/QBY2-KJ2Q] (last visited Mar. 18, 2019).

64. *See generally* RICHARD S. SUTTON & ANDREW G. BARTO, REINFORCEMENT LEARNING: AN INTRODUCTION (2017).

65. Salcedo, *supra* note 5, at 2, 8–10.

66. Ariel Ezrachi & Maurice E. Stucke, Algorithmic Collusion: Problems and Counter-Measures 4, 10 (unpublished manuscript for the 127th meeting of OECD Roundtable on Algorithms and Collusion 21–23 June 2017).

67. *See* Chris Brummer & Yesha Yadav, *Fintech and the Innovation Trilemma*, 107 GEO. L.J. 235, 276 (2019).

and human interviews.[68] It can also often be bought on the market as a commodity.[69] The more accurate the data, and the faster it can be analyzed, the stronger the ability to coordinate.

Performance is also affected by the quality and speed of the data analysis performed by the algorithm. A sophisticated or efficient algorithm might be able to mine the needed information from lower-quality data.[70] The computer's computational power and its ability to store and quickly retrieve data also affect performance. Finally, the computational procedure used by the algorithm affects performance. To illustrate, compare two paradigmatic cases: In the first one, algorithms react only to changes in input prices. In the second, algorithms react to changes in input prices and to prices set by competitors. Clearly, the second algorithm is more conducive to coordination.

2. Can Algorithms Affect Coordination?

Let us now relate the characteristics of algorithms to their ability to facilitate coordination. Although economists have yet to study in-depth the effects of algorithms on coordination, researchers are already split in their views of whether algorithms make a difference. While most researchers argue that at least under some market conditions, algorithms can make coordination more likely, others are more cautious, especially with regard to the design of autonomous algorithms that operate in complex settings.[71] Notably, most studies do not analyze the effect on coordination of the characteristics of algorithms and of the digital world in which they operate in a systematic manner.[72] This Article attempts to contribute to this important debate by doing so.

The analysis below assumes that the fourth condition for coordination—the existence of high entry barriers—is fulfilled. In markets where this is not true, a supra-competitive price will not be sustainable. Does the use of algorithms itself heighten entry barriers? Not necessarily, though in certain circumstances, in which the algorithm's special qualities or the unique dataset

68. *See, e.g.*, MAURICE STUCKE & ALLEN GRUNES, BIG DATA AND COMPETITION Policy (2016); JAMES MANYIKA ET AL., BIG DATA: THE NEXT FRONTIER FOR INNOVATION, COMPETITION, AND PRODUCTIVITY 21–22 (2011).

69. *See generally* Herbert Zech, Data as a Tradeable Commodity – Implications for Contract Law 1 (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3063153 [https://perma.cc/25MS-U4DG].

70. *See, e.g.*, Brummer & Yadav, *supra* note 67.

71. *See supra* note 3. For more cautious views on the ability of algorithms to coordinate see Ittoo & Petit, *supra* note 5.

72. For an exception, see, e.g., Ariel Ezrachi & Maurice E. Stucke, *Sustainable and Unchallenged Algorithmic Tacit Collusion* (Univ. of Tenn. Legal Studies Research Paper No. 266, Dec. 6, 2018).

on which it operates cannot be copied or easily reconstructed[73] (e.g., Google's database), the algorithm (or the data used in it) may create a significant comparative advantage.[74] Regardless, this Article focuses on cases in which entry barriers—of any origin[75]—are presumed to be high.

Where entry barriers are high, I argue that reaching a supra-competitive equilibrium by using algorithms operating in our digital world can be easier, relative to a similar market operating without algorithms. To show this, I explore how algorithms affect Stigler's three conditions.

Stigler's first condition, reaching an agreement (in economic parlance), is made easier by the use of algorithms. Several factors combine to reduce the difficulty in calculating a joint profit-maximizing equilibrium: (1) the greater availability of data, particularly real-time and more accurate data on market conditions, including digital price offers of competitors and suppliers of intermediate goods and services, as well as data on consumer preferences; (2) cheaper and easier data collection and storage tools (e.g., the cloud);[76] (3) advances in Internet connectivity which allow for cheaper and faster transfer of data;[77] and (4) the increasingly strong and sophisticated analytical power of algorithms due to advances in data science.[78]

Indeed, algorithmic sophistication makes it easier to solve the multidimensional problems raised by coordination, such as establishing a jointly profitable price in a market with differentiated products. Algorithms can be used not only to perform a single action, but also to determine and execute complex contingent strategies. Algorithmic sophistication also implies that fewer repeated games might be needed to reach a coordinated equilibrium. Indeed, studies performed by Google's artificial intelligence business, DeepMind, on algorithmic interactions found that algorithms with more

73. *See, e.g.*, Daniel L. Rubinfeld & Michal S. Gal, *Access Barriers to Big Data*, 59 ARIZ. L. REV. 339, 373 (2016).

74. *Id.* at 354.

75. Some conditions which characterize the digital world affect the height of entry barriers. For example, increased connectivity between consumers and suppliers through the Internet reduces the need to open physical stores. *See, e.g.*, Gal & Elkin-Koren, *supra* note 3, at 329. Yet large digital platforms that connect consumers and suppliers may provide the platform owner with advantages in data collection, and so may increase entry barriers. STUCKE & GRUNES, *supra* note 67.

76. Availability of data depends on the height of entry barriers into big data markets. *See generally* Rubinfeld & Gal, *supra* note 73.

77. In an EU study, approximately half the retailers who answered the questionnaire said they track online prices, and most use automatic software programs, sometimes called crawlers. *See Final Report on the E-commerce Sector Inquiry*, at 51, COM (2017) 229 final (May 10, 2017).

78. *See* discussion *infra*.

cognitive capacity sustained more complex cooperative equilibria.[79] Yet in situations in which the complexity of cooperation was too high or it was not rational to cooperate, the algorithms competed vigorously.[80] This implies that algorithms are subject to limitations, even if these are less demanding than those faced by humans performing similar tasks. Given the high stakes involved and the pace of technological developments in machine learning, it is envisioned that at least some of these technological limitations will be alleviated.[81]

Machine learning has the potential to play an important part in reaching a coordinated outcome. The algorithm may learn, even before it starts to operate in the market, when and which coordination is optimal. Such learning can be supervised or unsupervised. Supervised learning involves a process in which the algorithm determines the decisional parameters through an externally supervised training process, in which it is corrected when its predictions are incorrect.[82] The training process continues until the algorithm achieves a desired level of accuracy. Unsupervised learning involves a process in which the algorithm autonomously determines the decisional parameters by deducing decisional rules from correlations found in the input data (such as how past pricing patterns affected profitability).[83] Machine learning may thus enable the algorithm identify the best reactions to market conditions, given specified data. The artificial intelligence literature, while focusing on social dilemmas rather than on pricing issues, has shown that learning can lead to cooperative outcomes.[84]

Observe that to be jointly profitable, the coordinated price need not be the perfect profit-maximizing price (i.e., the Pareto optimal one, which is the highest price which still maximizes the firms' profits). For that to happen, firms may need data on factors such as the real production costs and production capacities of their competitors.[85] In some situations, such information can be indirectly observed or calculated, even if not perfectly. In

79. Leibo et al., *Multi-agent Reinforcement Learning in Sequential Social Dilemmas*, *in* PROCEEDINGS OF THE 16TH INTERNATIONAL CONFERENCE ON AUTONOMOUS AGENTS AND MULTIAGENT SYSTEMS 464, 471 (2017); *see generally* Ittoo & Petit, *supra* note 5, at 10–13.

80. *See* Leibo et al., *supra* note 79, at 467.

81. Ittoo & Petit, *supra* note 5, at 13.

82. *See, e.g.*, Schwalbe, *supra* note 5, at 8.

83. *See, e.g.*, *id.* at 9.

84. *See, e.g.*, Dipyaman Banerjee & Sandip Sen, *Reaching Pareto-Optimality in Prisoner's Dilemma Using Conditional Joint Action Learning*, 15 AUTONOMOUS AGENT & MULTI-AGENT SYSTEMS 91 (2007); Leibo et al., *supra* note 79.

85. *See, e.g.*, Susan Athey & Kyle Bagwell, *Collusion with Persistent Cost Shocks*, 76 ECONOMETRICA 493 (2008).

a repeated game, firms can signal such factors to each other, or the algorithm might be based on a profit-maximizing benchmark that was previously used in that market. Yet even when such information is not completely observable, firms may still find it profitable to coordinate so long as the price is the best approximation of the maximal price that can be set with the existing data, and is greater than the price which would have been set absent coordination. Hence, the fact that algorithms may not reach the perfect equilibrium does not lead to the conclusion that algorithms cannot facilitate coordination.

The fact that algorithms—unless their developers code them otherwise—make rational decisions, devoid of ego and biases, also potentially eases coordination, by making their decisions more predictable.[86] However, this factor could also lead in the other direction. "Rational" algorithms may be less affected than humans by forces such as guilt aversion, lying aversion, and group identity, which increase adherence to agreements and leads to more stable cooperation.[87] Much depends, of course, on the extent to which market players treat defection by an algorithm differently from defection by a human being.

A third effect of algorithms, which promotes Stigler's first condition, is that they shorten time lags of reaching new equilibriums when market conditions change. The speed and sophistication of algorithms, combined with the increased availability of real-time data and faster connectivity, enable them to quickly recognize changes in market conditions and to autonomously change their decisional parameters accordingly.[88] As a result, a new agreement is much easier and quicker to reach.

Fourth, and importantly for the legal analysis that follows, algorithms change the mode and dynamics of communication needed to reach an agreement. As John von Neumann, one of the founding figures of computer science, observed more than half a century ago, algorithms serve a dual purpose: as a set of instructions, and as a file, to be read by other programs.[89] The first use relates to the fact that an algorithm is a pre-set decision

86. *See generally* Ezrachi & Stucke, *supra* note 47, at 1792; Jan Blockx, *Antitrust in digital markets in the EU: policing price bots*, *in* DIGITAL MARKETS IN THE EU 75 (J. M. Veenbrink, ed., 2018). Observe that biases can nonetheless arise from biased data which is inputted into the algorithm.

87. *See, e.g.*, Robyn M. Dawes, Jeanne McTavish & Harriet Shaklee, *Behavior, Communication, and Assumptions About Other People's Behavior in a Commons Dilemma Situation*, 35 J. PERSONALITY & SOC. PSYCHOL. 1 (1977); Gary Charness & Martin Dufwenberg, *Promises and Partnership*, 74 ECONOMETRICA 1579 (2006).

88. For the ability of algorithms to change the decision parameters autonomously, see, e.g., Schwalbe, *supra* note 5, at 9.

89. Neumann, *supra* note 10, at 1–2.

mechanism, a "recipe" for making decisions.[90] The second use relates to the fact that algorithms can be instructed to read other algorithms, and to perform some action if the other program's content is of a particular kind.[91] This simple but fundamental idea highlights a central difference between human and algorithmic coordination: when an algorithm is transparent to others, another algorithm can "read its mind" and accurately predict all its future actions when given any specific sets of inputs, including changes in market conditions and reactions to other player's actions. Indeed, as Moshe Tennenholtz, Professor of Computer Science at the Technion has proven, this unique characteristic means that coordination can often be achieved in a one-shot game.[92] This is not true with regard to human interaction, in which one cannot accurately "read the mind" of another and predict all future actions. This algorithmic trait can also serve to limit misguided price wars.

To make this fundamental change in communication methods clearer, let us use a simple example. Player A adopts the following algorithm:

Algorithm A:

> Calculate best joint price under assumption that my price=Price set by Algorithm B;
>
> Set my price accordingly;
>
> Wait 10 seconds;
>
> Search for price set by algorithm B;
>
> If price set by algorithm B (larger or equal to) my price then repeat this set of actions every 5 seconds (loop);
>
> Else reduce my price by 50%.

Player B reads and understands the decision process adopted in Algorithm A, which enables it to accurately predict player A's reactions to changes in market conditions and to his prices. Algorithm A serves both as a self-commitment device, an indication of course for future action, and as an explicit threat of retaliation. B will then have strong incentives to adopt the following algorithm, should the price set by A be sufficiently close to the jointly profitable price:

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90. *Id.*

91. Even if different computer languages are used, an algorithm can "translate" the code.

92. Moshe Tennenholtz, *Program Equilibrium*, 49 GAMES & ECON. BEHAV. 363, 364 (2004).

Algorithm B:

Search for price set by algorithm A;

Set my price=price set by algorithm A;

Repeat this set of actions every 5 seconds (loop).

Algorithm B instructs the computer to compare player B's price to that of player A. This decision parameter is a rational reaction to the "price recipe" of Algorithm A. It also serves to motivate player A not to deviate, because any lower price he sets will be matched by B. This motivation is strengthened by the speed at which monitoring and reactions (price changes) take place. Indeed, the interaction between the players is based on each reasoning computationally about the other's algorithm.

The result is coordinated pricing as a direct consequence of simple leader-follower behavior, where B acts solely based on information about A's prices, which are available online. Moreover, although the interaction is asynchronous (since each reacts to prices set by the other), the speed of the Internet makes the resulting price changes almost synchronous.[93]

As the above example indicates, the use of an algorithm can send a strong and clear signal to other market players about several factors that are important for coordination:

1. The decisional parameters on which the algorithm will set its price, which can be observed by other market players even before any action is actually taken (A: Calculate best joint price under assumption that my price=Price B; B: Set my price=Price A);

2. The frequency of searches for deviations (A: Wait 10 seconds, and search for Price B; B: Repeat every 5 seconds);

3. The punishment for deviation by switching from a high payoff to a low payoff continuation equilibrium (A: Otherwise reduce my price by 50%; B: [Always] Set my-price=Price A).

Accordingly, this recipe for action, which contains an entire contingent plan for coordination in a few lines of code, creates both pre-agreement communication that the other party can "read" and understand, and a self-commitment device. It also increases the level of certainty for both parties. For

93. This example applies where both suppliers sell homogenous goods. However, as the Topkins case suggests, a more sophisticated algorithm can be used to set jointly profitable prices in much more complicated settings. There, the sellers sold different posters, in infrequent transactions. *See* Topkins, *infra* note 191.

example, both players are certain about what punishment to expect. Importantly, the use of algorithms limits the need for some forms of communication (e.g., verbal assurances of commitment or advance price change announcements) that were seen as necessary for establishing cooperation in a world based on human coordination.[94]

This implies that communication to competitors of future intended actions can be performed by simply making one's algorithm transparent and readable by (select) others' communication protocols.[95] The fact that the information is observable online eliminates the need to "drive by your competitor's petrol station" to know what he will charge, and creates immediate visibility of one's trade terms to multiple competitors. Moreover, to achieve transparency, the algorithm need not be directly observable. As the economist Bruno Salcedo argues, the analytical qualities of algorithms can be utilized to determine the decision processes of other algorithms, provided that the former have sufficient information about the decisions made by the latter under changing market conditions.[96] While it is more difficult to create transparency where decisions are taken by algorithms based on neural networks in which the decision process is not easily observable or explainable, if the specific neural network is transparent and can be copied, or if correlations in the algorithm's data inputs and outputs are observable, then the algorithm's outcomes may be predictable.

This observation cannot be overstated: the mere (direct or indirect) observation of the algorithm by competitors may, by itself, serve to facilitate coordination. As economic studies show, the ability to communicate price choices in oligopolistic markets may drastically change the market equilibrium, as collusion increases substantially and significantly.[97] The algorithm can

94. William E. Kovacic, Robert C. Marshall, Leslie M. Marx & Halbert L. White, Jr., *Plus Factors and Agreement in Antitrust Law*, 110 MICH. L. REV. 393, 417 (2011).

95. Recent studies focus on how machine learning can be used to let algorithms automatically discover and create the communication protocols needed to coordinate their behavior. Some examples include Sainbayar Sukhbaatar, Arthur Szlam & Rob Fergus, *Learning Multiagent Communication with Backpropagation*, 29 ADVANCES NEURAL INFO. PROCESSING SYS. 2252 (2016) (demonstrating the ability of algorithms to learn to communicate among themselves by creating a communication protocol); Jakob N. Foerster et al., Learning to Communicate to Solve Riddles with Deep Distributed Recurrent Q-Networks (2016) (unpublished manuscripts), https://arxiv.org/pdf/1602.02672.pdf [https://perma.cc/Z7F8-UJ2W] (creation of communication among algorithms for tasks which are fully cooperative, partially observable, sequential multi-agent decision-making problems. Communication is learned and agents communicate through actions). While these abilities might not, as of yet, be applied to pricing algorithms, they are likely to be added given rapid progress in artificial intelligence.

96. Salcedo, *supra* note 5.

97. *See* Christoph Engel, *Tacit Collusion: the Neglected Experimental Evidence*, 12 J. EMPIRICAL LEGAL STUD. 537 (2015).

communicate much more than price choices: it communicates a business strategy. Such communications need not be binding, but algorithms may strengthen this aspect as well.

This raises the question of the motivation of the user to make its algorithm and the data which it uses transparent. Exclusive access to algorithms and data can create a comparative advantage, and thus may be regarded as important trade secrets not to be shared with others. Yet at least some factors favor an inclination toward transparency. First, an important difference exists between firms whose comparative advantage lies in the creation of a pricing algorithm, and those in which it lies elsewhere. The latter have weaker incentives to protect the secrecy of their pricing algorithms and the data they rely on. Second, encoding can be used to create selective transparency. Third, transparency need only relate to the pricing part of the algorithm and not to all its functions. Finally, motivations for transparency will be determined by the balance between the increased profitability from coordination relative to the profitability of operating without it.[98]

The foregoing analysis also suggests that Stigler's second condition, detection of deviations from the status quo, is fulfilled more easily and quickly by algorithms. Due to their high levels of sophistication and reduced ingrained biases, algorithms may better differentiate between intentional deviations from coordination and natural reactions to changes in market conditions or even errors, which change the efficient status-quo, thereby preventing unnecessary price wars.[99]

Interestingly, the incentives to deviate in the first place are also reduced. Since technology enables the algorithm to react almost immediately to changes in a competitor's price, consumers may not be aware of ephemeral price differences between competitors and therefore may not switch between them. Competitors, acknowledging this fact, have weaker incentives to deviate.[100] Furthermore, the fact that digital markets have made it much easier for consumers to conduct transactions themselves has increased the number of small and frequent purchases. This, in turn, further reduces incentives to deviate, since the benefits from deviation are likely to be small and temporary. By way of analogy, correcting a mistaken assumption in an algorithm-driven market is like correcting a wrong turn on a road with many intersections, as opposed to accidentally getting on a highway with long stretches between interchanges. Thus, this reduces the need for credible punishments that devalue extra profits made during the deviation period, while at the same time

98. EZRACHI & STUCKE, *supra* note 5.
99. OECD, *supra* note 5, at 22.
100. *Id.*

increasing the credibility of an immediate switch from a collusive equilibrium to a competitive one, which would lower profits for all players in the future. In such an environment, changes in price may be almost immediately rescinded.

Stigler's third condition, creating a credible and sufficiently strong threat of retaliation against deviators, can also be more easily met by algorithms. Given their potentially high level of sophistication, algorithms can better calculate the level of sanctions necessary to discourage deviations. Moreover, algorithms may create a credible threat of retaliation, if changing their decision tree is not simple or change may take a long time relative to the frequency of market transactions.

Based on the foregoing analysis, algorithms operating in digital markets may facilitate coordination in three ways. First, they ease the fulfilment of Stigler's conditions. Second, and more interestingly, algorithms lessen the need to commit to Stigler's conditions a priori. As elaborated, they can more quickly recalculate one's optimal reaction, thereby reducing the need for an optimal equilibrium in the first round, and they lower incentives to deviate, thereby reducing the need for explicit ex ante commitments or threats of strong punishment.[101] Accordingly, algorithms operating in the digital world increase the likelihood of coordination without the need for strong pre-action commitments and threats. Finally, algorithms may strengthen not only players' ability to reach an agreement, but also their incentives to do so. One factor which affects such incentives is the risk of detection by enforcement agencies and private plaintiffs. A study performed by Google Brain has shown that algorithms can autonomously learn how and when to encrypt messages, given a specified secrecy policy, in order to exclude other algorithms from the communication.[102] Unless third parties have a way of determining when the conduct of algorithms is based on such encryption, detection will become much harder. Furthermore, should algorithmic signaling and interactions be sufficient to sustain a supra-competitive equilibrium, algorithms reduce the need to meet in the real world, thereby further reducing the chances of getting caught. Accordingly, in markets where entry barriers are high and algorithms can facilitate meeting the conditions for coordination, the appearance and stability of supra-competitive prices may increase.[103]

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101. *See supra* Section II.B.1

102. *See generally* Martin Abadi & David G. Anderson, Learning To Protect Communications with Adversarial Neural Cryptography (2016) (unpublished manuscript), https://arxiv.org/pdf/1610.06918v1.pdf [https://perma.cc/AG5C-73UQ].

103. *See also* OECD, *supra* note 5, at 35 ("Algorithms might affect some characteristics of digital markets to such an extent that tacit collusion could become sustainable in a wider range

This is not to say that algorithms can facilitate coordination in all circumstances. Where entry barriers are low, or where one or more of Stigler's conditions cannot be effectively met, coordination will not take place. This may be the case, for example, in markets where demand fluctuations are significant and difficult to distinguish from deviations from the equilibrium, or where the relevant data are not easily accessed by all competitors.[104] As Ashwin Ittoo and Nicolas Petit, Professors of Information Systems and Law, respectively, at the University of Liege, argue,"[w]hile we do not deny the fact that smart pricing agents can enter into tacit collusion and that regulators may be right to be vigilant, we find that there are several technological challenges in the general realm of [reinforcement learning] that mitigate this risk."[105] In particular, current algorithmic sophistication may not be sufficient to overcome coordination obstacles in complex setting, especially where competitors lack information on their rivals' business strategies, input prices, and demand forecasts.[106] Indeed, algorithms provide no panacea to these coordination problems, which similarly plague human-facilitated coordination. Nonetheless, as shown above, at least in some circumstances, algorithms may be able to reduce their significance. For example, business strategies can be communicated though the coding and transparency of the algorithms.[107] Furthermore, given the high profits to be had from coordination, it is envisioned that computational complexity problems[108] will be reduced as firms develop more sophisticated algorithms.[109]

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of circumstances possibly expanding the oligopoly problem to non-oligopolistic market structures.").

104. *See* Edward J. Green & Robert H. Porter, *Noncooperative Collusion Under Imperfect Price Information*, 52 ECONOMETRICA 87 (1984).

105. Ittoo & Petit, *supra* note 5, at 1. For a skeptical view, see Ulrich Schwalbe, Algorithms, Machine Learning, and Collusion 16 (2018) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3232631 [https://perma.cc/HJ4U-UP3N] ("[C]oordinated behaviour of algorithms is a possible outcome, but it is not as quick and easy or even unavoidable as it is often assumed in the legal discussion of algorithmic collusion.").

106. Ittoo & Petit, *supra* note 5, at 11–12.

107. *See supra* notes 89–92 and accompanying text.

108. *See generally id.* at 13.

109. *Id.* ("The introduction of Deep RL agents (like Deep Q-Networks) on markets may alleviate some of the obstacles to tacit collusion that we have identified. In particular, Deep RL agents may be quite effective at learning the Q-values of rival oligopolists."); Schwalbe, *supra* note 5, at 3 ("Considering the rapid progress in AI-research [] it cannot be excluded that in the future, algorithms may learn to communicate and to behave in a collusive way.").

3. *Price Discrimination and Coordination*

So far we have assumed that coordinating competitors set similar, although supra-competitive, trade terms for consumers. But in the digital world, another factor comes into play: as more data are gathered about each consumer's preferences, a personalized "digital profile" can be created through the use of algorithms that calculate and update consumers' elasticity of demand in real time.[110] This digital profile can be used by suppliers to increase their profits, by setting the maximal price that each consumer is willing to pay ("personalized pricing").[111] This, in turn, implies that setting one price for all consumers may be welfare-reducing for suppliers, and that more factors must enter into the coordinated equilibrium, making coordination more complicated.

For the purposes of the analysis below, let us assume that personalized pricing can be practiced, even if not to a perfect extent, given factors such as unclear price signals on the part of consumers, unknown demand for new products, and the effects on demand of changing market conditions. How is coordination affected by such opportunities for price discrimination? If no firm has a significant comparative advantage over other competitors, then incentives to engage in coordination may be increased. This is because, without coordination, it will be more difficult to reach a jointly profitable equilibrium.

At the same time, increased information about consumers' real-time preferences also makes it more difficult to coordinate trade terms. The exponential increase in the number of parameters that must be taken into account in calculating personalized prices, as well as in the calculation of a jointly profitable price, introduces "noise" into the system.[112] Furthermore, the ability to coordinate depends, inter alia, on the information about each consumer's preferences held by each supplier.

So, what should be expected? Firms may reach market-division agreements (e.g., Firm A sell to businesses and Firm B sell to individuals), where they all agree not to enter each other's market segment, and each can exploit information regarding consumer preferences in its designated market. Another possibility is that all firms will come to possess similar information, either because consumers' individual preferences are easily calculated, or because all firms refer to a common database and similar data analysis tools. If so, firms can in theory coordinate with respect to the prices charged to each and every

110. For an example of a digital profile which predicts defaults on loans, see Talia B. Gillis & Jann Spiess, *Big Data and Discrimination*, 86 U. CHI. L. REV., at 1 (forthcoming 2019).

111. *See, e.g.*, Oren Bar-Gill, *Algorithmic Price Discrimination: When Demand Is a Function of Both Preferences and (Mis)Perceptions*, 86 U. CHI. L. REV. (forthcoming 2019); Harrington, *supra* note 6, at 54.

112. *See, e.g.*, Nicholas Petit, *Antitrust and Artificial Intelligence: A Research Agenda*, 8 J. EUROPEAN COMPETITION L. & PRAC. 361, 361 (2017).

consumer. While such coordination would be almost impossible for humans, it can be facilitated by algorithms under certain market conditions. Alternatively, the difficulties involved in coordination might lead to market equilibriums that, while not fully embracing personalized pricing, would still increase all player's profits under the circumstances.

Observe, however, that the threat of personalized pricing might not be as significant as some claim, for two business-related reasons. First, as Amazon learned the hard way, personalized pricing might create a public backlash.[113] Second, and relatedly, in order to avoid personalized pricing, consumers might prefer to browse anonymously. This, in turn, will limit sellers' ability to engage in targeted advertising. The financial loss from the reduced ability to better identify those potential consumers who might buy a product might well be larger than the loss from not being able to perform personalized pricing. When this is true, personalized pricing will not be practiced.

A related issue involves the use of consumers' digital profiles to individualize products to better meet the preferences of different consumers. This, in turn, may lead to product heterogeneity, which makes coordination harder to sustain. The same observations made above apply here as well. Undoubtedly, a focal point on which to base a coordinated equilibrium may be more difficult to find where differentiated products are offered. Yet algorithms may ease this difficulty—even if not erase it—by engaging in a quicker and more accurate multi-factored analysis.

4. *Algorithms and Harm to Welfare*

Undoubtedly, the effects of algorithms on coordination should be studied further by economists and computer scientists. Yet the potential effects of algorithmic-facilitated coordination are too significant to be ignored until such detailed studies are performed. The analysis presented above, detailing how the characteristics of algorithms operating in the digital economy can, under certain circumstances, facilitate coordination and guide the development of a legal framework aimed at addressing this issue.

By way of summary, I relate briefly to claims raised by some researchers that algorithms do not create significant concerns. Ulrich Schwalbe, Professor of Economics at the University of Hohenheim, argues that "it is doubtful whether algorithms raise barriers to entry,"[114] the fourth condition necessary

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113. *Test of "dynamic pricing" angers Amazon customers*, WASH. POST (Oct. 7, 2000), http://www.citi.columbia.edu/B8210/read10/Amazon%20Dynamic%20Pricing%20Angers%20Customers.pdf [https://perma.cc/VV5H-5EPU]. Nonetheless, the tolerance of consumers to price discrimination may change, as it becomes more prevalent, or once it is connected with personalized (rather than homogenous) products.

114. Schwalbe, *supra* note 5, at 4.

for coordination. As noted above, I generally agree with this claim. Yet it does not lead to a conclusion that algorithms do not matter. Rather, in markets in which entry barriers are high, algorithms can make coordination easier.

It may be claimed that the fact that, thus far, only a small number of cases involving algorithmic-facilitated cartels have been brought by competition authorities indicates that algorithms have no significant effect. Yet low levels of current enforcement may not reflect market behavior, given that enforcement agencies have only begun to wrap their heads around this new technological challenge, which may require adding computer scientists to their teams. Alternatively, current levels of enforcement may signify that market participants have only recently begun to experiment with the use of algorithms to set prices. Furthermore, it may indicate, as elaborated in the next Part, that legal tools are insufficient to capture some instances of algorithmic-facilitated coordination.[115] Whatever the reason, given that both theory and experimental evidence already point to the potential coordination-facilitating capabilities of algorithms, it is urgent that we prepare for such algorithmic interactions.[116]

A related claim is that none of the cases feature human-less implicit coordination, and that in those cases that were brought, algorithmic technology simply removed the last obstacle to it.[117] While autonomous coordination is probably the most theoretically intriguing scenario, cases in which algorithms tilt the balance towards coordination, because all other market conditions conducive to coordination already exist, should not be treated lightly. Their effects, compared to markets without algorithms, may well be significant. And given the exponential growth in our understanding and applications of machine learning, we cannot afford to wait until algorithms become completely autonomous to check whether our laws are welfare-enhancing.

Some argue that algorithms have difficulties in meeting the need to communicate, which is a fundamental requirement for coordination.[118] While communication is indeed a condition for coordination, as elaborated above, the characteristics of algorithms, and the digital world in which they operate, create communication. Algorithms are "recipes for future action" that increase clarity of how trade terms will be set by them, and how they will react to their competitors' terms.[119] By enabling other algorithms to "read their minds"—either directly or indirectly, even before any action was taken by them—they

115. *See infra* Part III.
116. *See* Harrington, *supra* note 6, at 69.
117. Ittoo & Petit, *supra* note 5, at 2–3.
118. *Id.* at 3.
119. *See* Von Neumann, *supra* note 89; *see also* Harrington, *supra* note 6, at 46–47.

limit the need for direct communication or physical meetings. Also, due to the conditions in the digital world, there is lesser need for communication ex ante. Rather, algorithms can coordinate actions in a short sequence of low-value games.[120]

Another claim is that coordination is more difficult to achieve as algorithms become more and more sophisticated.[121] The level of sophistication of an algorithm is determined by those employing it. Furthermore, as the example above indicated, algorithms can be simple. Moreover, sophisticated analysis, which relates to changing market conditions, can strengthen the equilibrium, rather than weaken it.

So how do we ensure that welfare is increased in the data-driven algorithmic economy? What follows is an exploration of two potential tools to limit the negative effects of algorithmic-facilitated coordination: market-based solutions and antitrust law.

III. MARKET-BASED SOLUTIONS

Can the market devise its own solutions to algorithmic coordination? The answer is a partial yes. As shown by Gal and Elkin-Koren, the use of algorithms by consumers can counteract at least some of the effects of algorithmic-facilitated coordination by suppliers.[122] Put differently, it sometimes takes a (consumer) algorithm to beat a (supplier) algorithm.

Algorithmic consumers (digital butlers) are algorithms employed by consumers which make and execute decisions for the consumer by directly communicating with other systems through the Internet.[123] The algorithm automatically identifies a need, searches for an optimal purchase, and executes the transaction on behalf of the consumer. Such algorithms can significantly reduce search and transaction costs, overcome biases, and enable more rational and sophisticated choices.[124] The analysis below assumes that algorithmic consumers are coded to best serve the consumer. This assumption is relaxed later on.

Algorithmic consumers are already part of our digital marketplace. In some industries, such as stock trading, algorithms automatically translate their results into buying decisions;[125] consumers can already purchase a washing machine

120. *See* Tennenholtz, *supra* note92.
121. Ittoo & Petit, *supra* note 5, at 2.
122. *See* Gal & Elkin-Koren, *supra* note 3, at 331.
123. *See id.* at 313.
124. *See id.* 313–15.
125. *See* Shobhit Seth, *Basics of Algorithmic Trading: Concepts and Examples*, INVESTOPEDIA (Mar. 14, 2019), https://www.investopedia.com/articles/active-trading/101014/basics-

that automatically restocks detergent;[126] and a British application monitors prices in the energy market and automatically switches suppliers when it is profitable to do so.[127] Scientists envisage that in the near future algorithmic consumers will become the rule rather than exception for an exponentially increasing number of transactions—realizing a vision of a world where "humans do less thinking when it comes to the small decisions that make up daily life."[128]

Algorithmic consumers have the potential to counteract at least some of the negative welfare effects of algorithmic-facilitated supplier coordination. The Section below explores several such ways, all based on the idea that instead of passively accepting suppliers' decisions, consumers take the reins and actively change market conditions.

Algorithmic consumers can create buyer power if a sufficiently large number of consumers use a specific algorithm, or if several algorithmic consumers coordinate their conduct.[129] This, in turn, may allow consumers to counteract the power of suppliers. The aggregation of consumers can also make transactions larger and less frequent, thereby increasing suppliers' incentives to deviate from the coordinated equilibrium,[130] or to transact "off the digital grid." Such negotiations need not necessarily involve human intervention.

Algorithmic consumers can also be coded to include decisional parameters designed to eliminate, or at least reduce, some market failures.[131] Algorithms are sufficiently flexible to include considerations such as long-run effects on market structures that might harm consumers. For example, an algorithm might be able to recognize coordination among suppliers and refrain from doing business with these suppliers until prices are lowered. Alternatively, to strengthen incentives for new suppliers to enter the market, the algorithm might be coded to always buy some portion of certain goods from at least one

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algorithmic-trading-concepts-and-examples.asp [https://perma.cc/5AWM-7MR3]; *Algorithmic Trading*, WIKIPEDIA, https://en.wikipedia.org/wiki/Algorithmic_trading [https://perma.cc/EL8D-64G4].

126. IBM INST. FOR BUS. VALUE, ADEPT: AN IOT PRACTITIONER PERSPECTIVE, DRAFT COPY FOR ADVANCED REVIEW 13 (2015).

127. FLIPPER, https://flipper.community/ [https://perma.cc/D6QW-6HZU] (last visited Mar. 20, 2019).

128. Danny Yadron, *Google Assistant Takes on Amazon and Apple to Be the Ultimate Digital Butler*, GUARDIAN (May 18, 2016), https://www.theguardian.com/technology/2016/may/18/google-home-assistant-amazon-echo-apple-siri [https://perma.cc/7VQC-ADEW].

129. *See* Gal & Elkin-Koren, *supra* note 3, at 311.

130. *See id.* at 330.

131. *Id.*

new source. Of course, including such decisional parameters requires sophisticated modeling and analysis of market conditions, but given ongoing advances in data science, this will become easier.[132] It also requires incentives for collective action, given that refraining from doing business with certain suppliers may be personally costly to individual customers, while disrupting coordination is a public good that benefits all customers since it may eventually lead to lower prices. Such incentives can be created when many consumers are aggregated through an algorithmic consumer.

Finally, algorithmic consumers may reduce the ability of suppliers to engage in personalized pricing.[133] By aggregating the choices of different consumers into one virtual buyer, algorithmic consumers can obscure consumers' personal demand curves (what might be called "anonymization-through-aggregation").[134] More precisely, if consumers are aggregated into sufficiently large consumer groups, suppliers lose the ability to collect data on consumers' individual preferences and to discriminate among them.

In short, algorithmic consumers can potentially improve market dynamics and limit the harmful effects of algorithmic-facilitated supplier coordination without need for legal intervention. Rather, their regulating power resides in the proactive actions of consumers.

This market-based solution is not, however, a panacea. Three main potential limitations can be identified. First, the use of algorithmic consumers may itself infringe on antitrust laws, if they are found to engage in anti-competitive agreements or to abuse their market power.[135] Therefore, it is important to clarify the rules that will be applied to the use of buyer power to counteract supplier power.[136] The second concern is that the market for algorithmic consumers could be dominated by digital butlers (such as Amazon's Alexa) that are not benign, but rather serve the purposes of their suppliers.[137] Indeed, the major digital platform owners are already vigorously competing in the supply of digital assistants.[138] As observed by Ezrachi and

132. *See, e.g.*, Ittoo & Petit, *supra* note 5; Schwalbe, *supra* note 5.

133. Gal & Elkin-Koren, *supra* note 3, at 311 ("We do not relate to the welfare effects of price discrimination.").

134. *Id.*

135. *Id.* at 345.

136. On the regulation of buyer power, see generally PETER C. CARSTENSEN, COMPETITION POLICY AND THE CONTROL OF BUYER POWER (2017).

137. *See* EZRACHI & STUCKE, *supra* note 5, at 191–92.

138. *See* Mark Prigg, *Apple Unleashes Its AI: 'Super Siri' Will Battle Amazon, Facebook and Google in Smart Assistant Wars*, DAILY MAIL (June 13, 2016), http://www.dailymail.co.uk/sciencetech/article-3639325/Apple-unveil-SuperSiri-Amazon-Google-smart-assistant-wars.html [https://perma.cc/P67F-PDL9].

Stucke, their incentives to do so are straightforward: digital assistants are likely to become consumers' gateway into the digitized world.[139] This, in turn, strengthens the incentives of current platform owners to pursue dominance in the market for algorithmic consumers.[140] Finally, suppliers may take actions to limit the operation of algorithmic consumers.

Other market solutions may also limit the ability of suppliers to engage in algorithmic-facilitated coordination. For example, digital literacy, which ensures that consumers know their options and understand how supplier algorithms work and interoperate, may affect consumer choices.[141] Yet market solutions are, at best, partial. Furthermore, consumers might not be aware that prices are supra-competitive or that their suppliers coordinate their prices. Accordingly, I now turn to legal solutions that can complement or support such market solutions.

IV. LEGAL SOLUTIONS: ALGORITHMIC INTERACTIONS AS AGREEMENTS IN RESTRAINT OF TRADE?

"Smart coordination" by suppliers requires "smart regulation"—setting rules that limit the harms of increased coordination while ensuring that the digital economy's welfare-enhancing effects are not lost.[142] The question is whether antitrust law, which deals with anti-competitive conduct, is fit for the task.[143] This question arises because current legal tools were designed to deal with human facilitation of coordination. New and improved ways to coordinate, as well as the potential scale and scope of the resulting conduct, were not envisioned when antitrust prohibitions were fashioned. It is necessary to determine whether algorithmic interactions that lead to price coordination can and should be caught under existing laws, and if so, to what extent.

Antitrust law currently relies on the exploitation of human limitations in order to increase competition in the market. For example, it prevents market

139. *See* EZRACHI & STUCKE, *supra* note 5, at 191–92.

140. *See id.*

141. Michal S. Gal, *Algorithmic Challenges to Autonomous Choice*, MICH. TELECOMMS. & TECH. L. REV. (forthcoming 2019).

142. For a similar suggestion, see EZRACHI & STUCKE, *supra* note 5; OECD, *supra* note 5, at 46–47.

143. For some discussions of this issue, see, e.g., EZRACHI & STUCKE, *supra* note 5; OECD, *supra* note 5; Directorate for Fin. & Enter. Affairs Competition Comm., *Algorithms and Collusion – Summaries of Contributions* (June 2017) (summarizing each country's contributions to the OECD Roundtable on Algorithms and Collusion); Peter Picht & Benedikt Freund, *Competition (Law) in the Era of Algorithms* (Max Planck Inst. for Innovation & Competition Research Paper No. 18-10, May 15, 2018), https://ssrn.com/abstract=3180550 [https://perma.cc/K9SY-4ZQP].

players from discussing anti-competitive agreements and from using the legal system to implement them in order to make it harder to reach and enforce such agreements.[144] But in the algorithmic world, where coordination, detection, and punishment are automated, questions of reaching or enforcing explicit agreements fall in importance. Similarly, the law is based on the assumption that humans' capacity to respond quickly to market changes is limited when numerous or multi-factored decisions must be taken; algorithms are only limited by their computational powers. Furthermore, the current legal treatment of illegal agreements is generally focused on the means of communication used by market players in order to coordinate.[145] When means of communication change, the law might no longer capture conduct which is socially harmful. The challenge is, therefore, to determine to what extent we can rely on existing laws in order to prevent new ways of engaging in socially harmful anti-competitive conduct. More fundamentally, given changes in modes of communication, which may facilitate many more instances of conscious parallelism, we need to explore whether it is still socially beneficial to consider such conduct to be legal. The answers to these questions also serve as a basis for exploring whether new regulatory tools are needed.

The analysis below focuses on how to apply the prohibition of agreements in restraint of trade to algorithms that facilitate coordination. For liability to arise, market participants must be found to have engaged in an agreement which restrains trade, with no offsetting procompetitive effects.[146] The application of additional existing regulatory tools, such as those designed for shared monopolies and merger reviews, is left for future research. Accordingly, the analysis below strives to explore and provide preliminary answers to two interconnected questions that stand at the basis of designing a welfare-enhancing policy toward the use of coordination-facilitating algorithms:

1. Do algorithms that facilitate coordination fulfill the requirement for "an agreement" as defined in antitrust laws, and, if so, under what conditions?
2. If the answer to the first question is positive, what exactly do we wish to prohibit, and can we spell this out clearly for market participants?

The answer to the first question is quite often positive. The real challenge lies in the second question, which focuses on whether and under what

144. *See, e.g.*, Harrington, *supra* note 6, at 46–47.

145. *See, e.g.*, Page, *supra* note 17, at 599–601; Kaplow, *supra* note 20; Harrington, *supra* note 6, at 46–47.

146. *See* Sherman Anti-Trust Act, 15 U.S.C. § 1 (2018).

conditions algorithms should be treated as engaging in "restraint of trade." The answers to these questions also depend on our ability to set rules that can also be justified based on decision-theory considerations,[147] ensuring that the actual costs of enforcement do not outweigh its benefits given institutional limitations.

One last general note is in order. It is important to separate two questions that arise: whether an illegal agreement has been reached, and who is legally liable for it. This Article focuses on the former.

A. Coordination-Facilitating Algorithms as "Agreements"

1. *General: Agreement, Plus Factors and Facilitating Practices*

For liability to arise from coordinated conduct, an "agreement" must be found to exist.[148] But what is an agreement? Despite the importance of this concept and the numerous cases and commentary which have strived to define it, the term's meaning remains vague and its boundaries are contested.[149] Yet some principles are largely agreed upon. As the Supreme Court noted in *Bell Atlantic Corp. v. Twombly*, an agreement must involve either express or tacit (i.e., implicit) formulation.[150] Independent conduct, in which competitors act in parallel without regard to one another's actions, does not constitute agreement, nor does mere interdependent conduct (conscious parallelism), in which firms take into account how other firms are expected to react.[151]

Despite wide agreement on these principles, some prominent scholars suggest that the term "agreement" is sufficiently broad to capture conscious parallelism. This argument was famously raised (though recently repudiated) by Richard Posner,[152] who argued that conscious parallelism involves the making and acceptance of an offer through conduct, and therefore, literally and materially fulfills the conditions for an agreement. This view, dormant for many years, was recently endorsed by Harvard University Law Professor Louis

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147. On decision-theory in antitrust, see, e.g., C. Frederick Beckner III & Steven C. Salop, *Decision Theory and Antitrust Rules*, 67 ANTITRUST L.J. 41 (1999).

148. The word "agreement" is used broadly to include alternative wordings (e.g., arrangement).

149. Contrast, for example, KAPLOW, *supra* note 20; Page, *supra* note 17; Kovacic, *supra* note 94.

150. Bell Atl. Corp. v. Twombly, 550 U.S. 544 (2007); *see* William H. Page, *Tacit Agreement Under Section 1 of the Sherman Act*, 81 ANTITRUST L. J. 201, 209–10. The use of the term "tacit agreement" is confusing, since it is sometimes used to indicate conscious parallelism. I assume that the Court intended to differentiate between these terms.

151. *Id.* at 601–02.

152. RICHARD A. POSNER, ANTITRUST LAW: AN ECONOMIC PERSPECTIVE 146 (1976). More recently, Posner repudiated his view. Richard A. Posner, *Review of Kaplow, Competition Policy and Price Fixing*, 79 ANTITRUST L.J. 761, 766 (2014).

Kaplow.[153] Analyzing economic models as well as United States' case law, Kaplow makes a strong and convincing case that the distinction between express collusion and conscious parallelism is blurry, and the definition of "agreement" can include both.[154] Furthermore, he shows that some Supreme Court precedents are sufficiently wide as to be interpreted to include conscious parallelism.[155] He also argues that the distinction between the two does not serve social welfare. The main problem with this view lies in the practical limitations of prohibiting conscious parallelism. Indeed, the problem of fashioning a clear prohibition and an applicable remedy has been one of the main reasons for treating conscious parallelism as legal.[156] Kaplow addresses this problem by suggesting that the prohibition be structured to incentivize market participants to act as if in a one-shot game without fines, which would lead to competitive prices. He also argues that if the remedy is sufficiently strong, market players will have sufficiently strong motivations not to engage in the prohibited conduct.[157] However, practical questions still remain: how to clarify what conduct is prohibited, and whether courts can readily apply such a prohibition in practice. Posner recently acknowledged these problems, citing them as a reason for repudiating his earlier views.[158] For the purpose of this Article, I assume that conscious parallelism is not currently captured by the law.

The focus thus shifts to the definition of tacit agreements, which come under the law. This concept is not clearly defined.[159] Its name indicates that an agreement is implied or indicated, but not explicitly expressed.[160] While clearly some form of meeting of minds is necessary, neither the law nor Supreme Court precedents clearly clarify what constitutes an illegal meeting of minds that could be differentiated from the meeting of minds that stands at the basis of conscious parallelism. In both cases, the parties take into account the

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153. KAPLOW, *supra* note 20, at 77–82.

154. *Id.*

155. *Id.* With regard to the relevance of *Twombly*, it is argued that as the Court did not carefully articulate any concept of agreement, reconcile its statements with prior conflicting statements, or discuss its reasons for its interpretation, its relevance should be limited. *Id.* at 88–92.

156. *See, e.g*, Donald F. Turner, *The Definition of Agreement Under the Sherman Act: Conscious Parallelism and Refusals to Deal*, 75 HARV. L. REV. 655, 657–84 (1962).

157. *See* KAPLOW, *supra* note 20.

158. Posner, *supra* note 152, at 766.

159. Furthermore, it confused matters further by stating that "allegations of parallel conduct . . . must be placed in a context that raises a suggestion of a preceding agreement." Bell Atlantic Corp. v. Twombly, 550 U.S. 544, 557 (2007). This implies that the parties have already formed an express agreement, which they then implement.

160. KAPLOW, *supra* note 20, at 36.

expected reactions of their competitors; in both, some flow of information is necessary; in both, there must be intent to engage in coordinated conduct.

Most commentators and courts suggest a definition that focuses on communication between competitors which signal intent to act in a coordinated way, and their reliance on each other to follow suit.[161] The mode of communication, as well as the types of information communicated, play a decisive role under such definitions. Building on lower court precedents, University of Florida Law Professor William Page suggests that tacit agreement be defined to include two-staged situations in which competitors "clarify their expectations about one another's intentions by communication, then act consistently with the communications."[162] No exchange of express assurances to act uniformly is required.[163] An additional requirement is that communication take place by means that lack efficiency justifications.[164] This condition ensures that the communication would not have taken place regardless of its coordinating effects, and it reduces the risk that deterring the communication will harm social welfare.

To assist in separating conscious parallelism from tacit agreement, lower courts have endorsed the concept of "plus factors"—i.e., circumstantial facts or factors that go beyond mere conscious parallelism, from which an agreement can be indirectly inferred.[165] Plus factors can be negative or positive. Negative plus factors are the fruits of economic reverse-engineering: absent an agreement, it is improbable that parallel conduct would have arisen under the given market conditions.[166] Since parallel conduct took place, it can thus be inferred that an agreement was reached between market participants. Similar bids for made-to-order products exemplify this category: they could not have occurred absent prior agreement among the bidders. Interestingly, algorithms make proving the existence of negative plus factors more difficult. This is because their characteristics make it easier to reach parallel conduct without an agreement. This, in turn, increases what Kaplow calls the "paradox of proof":

161. *See* Kaplow, *supra* note 20; Harrington, *supra* note 6, at 25–46. Interestingly, Professor Harington suggests that overt communication is not a necessary part of a collusive scheme, which he defines as when firms use strategies that embody a reward-punishment scheme which rewards a firm for abiding by the supra-competitive outcome and punishes it for departing from it. Yet the requirement for communication reduces false positives and serves as an informative signal for the presence of collusion. *See id.*

162. Page, *supra* note 17, at 608.

163. *Id.*

164. *Id.*

165. *See, e.g.*, OECD, *supra* note 5, at 20; Kovacic et al., *supra* note 94.

166. *See* AREEDA & HOVENKAMP, *supra* note 13, at 181–82; Harrington, *supra* note 6, at 27 (unnatural parallelism).

the more conducive are existing natural market conditions to coordination, which makes price elevation and the resultant harm to social welfare more likely, the less the need for specified means of communication such as those currently required to prove an agreement, and the lower the chance that an agreement will be proven and the conduct condemned.[167]

Positive plus factors constitute avoidable acts that indirectly prove a shared commitment to a common cause.[168] Yet the scope of application of this requirement is unclear and sometimes misleading.[169] Some examples of plus factors used by courts can as readily indicate conscious parallelism, and therefore add to the confusion. For example, "acts against one's self-interest," which make sense only if we read them to include acts against one's short-term interests, also characterize conscious parallelism: a competitor does not lower its price below the jointly profitable level, even though it can profit in the short run, because it acknowledges that such an action might trigger retaliation by its competitors, which would lower its profits in the long run.[170]

Other examples are less problematic. These include, for example, meetings of competitors without other justifications, and private disclosure of future price changes.[171] Importantly for our discussion below, while it is settled law that "the *form* of [communication] should not be determinative of its legality[,]"[172] the requirement that the communication lack efficiency justifications has made many courts reluctant to find an agreement when the communication is public and relates to current or future trade terms.[173] Public price announcements have generally been treated as creating transparency for consumers as well as shareholders.[174] Some courts put heavy emphasis on pre-action explicit communication of promises to act in a certain way and threats to punish deviations.[175]

167. KAPLOW, *supra* note 20, at 124–73.

168. While courts vary with regard to the scope of the concept, some core examples of plus factors are widely accepted. Compare, for example, Kovacic et al., *supra* note 94; RICHARD A. POSNER, ANTITRUST LAW 55–93 (2nd ed. 2001); KAPLOW, *supra* note 20.

169. *See, e.g.*, KAPLOW, *supra* note 20, at 111–14.

170. *See id.* at 111.

171. *See* Page, *supra* note 17, at 221.

172. *In re* Coordinated Pretrial Proceedings in Petroleum Prods. Antitrust Litig., 906 F.2d 432, 447 (9th Cir. 1990).

173. Dennis W. Carlton, Robeert H. Gertner & Andrew M. Rosenfeld, *Communication Among Competitors: Game Theory and Antitrust*, 5 GEO. MASON L. REV. 423, 428–29 (1997) (communications are most likely to be anticompetitive if they are private rather than public, if they relate to current and future prices rather than historical prices, and are repeated rather than isolated).

174. *Id.* at 432.

175. *See* discussion in Page, *supra* note 17; Kovacic et al., *supra* note 94.

The related concept of facilitating practices is also relevant to our discussion. Facilitating practices are positive, avoidable actions that allow competitors to more easily and effectively achieve coordination by overcoming impediments to coordination, in a way that goes beyond mere interdependence.[176] In doing so, they increase competitors' incentives to cooperate, despite their divergent interests.[177]

When firms expressly agree to adopt a facilitating practice—for example, agreeing to post their prices in advance—that agreement, by itself, may constitute an agreement in restraint of trade.[178] More relevant to our discussion are instances under which facilitating practices themselves are prohibited. Toward this end, two main (and partially overlapping) legal routes are possible.[179] The first treats the adoption of facilitating practices, by itself, as a basis for liability. This route was first suggested by the late Harvard University Professor Donald Turner but was never adopted.[180] As elaborated below, given the shortcomings of existing law in addressing algorithmic-facilitated coordination, the time may be ripe to rethink this position. The second route, which is currently applied, treats the adoption of facilitating practices as a sub-category of plus factors: under certain circumstances they serve as indirect indications of an "agreement."[181] Both legal routes recognize that a facilitating practice can also create procompetitive effects, such as providing consumers and potential entrants with more accurate information necessary for their decisions.[182] Therefore, both also include tools designed to ensure that procompetitive justifications are included in the analysis. Yet they are conceptually different. The former prohibits the conduct itself, given its potential anticompetitive tendencies. The latter is evidentiary: the use of facilitating practices serves as an indirect circumstantial indication of an agreement between parties operating in the market.

The logic behind the existing rule can be explained as follows. Facilitating practices are avoidable actions which change market conditions in a way that

176. *See, e.g.*, Steven C. Salop, *Practices that (Credibly) Facilitate Oligopoly Coordination*, *in* NEW DEVELOPMENTS IN THE ANALYSIS OF MARKET STRUCTURE 265, 271 (Joseph Stiglitz & G. Frank Mathewson eds., 1985); Charles A. Holt & David T. Scheffman, *Facilitating Practices: The Effects of Advance Notice and Best-Price Policies*, 18 RAND J. ECON. 187 (1987); Ian Ayres, *How Cartels Punish: A Structural Theory of Self-Enforcing Collusion*, 87 COLUM. L. REV. 295 (1987); Page, *supra* note 40; KAPLOW, *supra* note 20, at 276–85.

177. Salop, *supra* note 176, at 434–35.

178. *Id.* 425–26.

179. KAPLOW, *supra* note 20, at 276.

180. Turner, *supra* note 156, at 666–67.

181. Page, *supra* note 20, at 415–16.

182. *Id.*

makes it easier to coordinate. In the absence of procompetitive justifications for their adoption, firms would not have engaged in such conduct unless they served as an indirect communication device to signal to each other their intent to engage in coordinated conduct and their reliance on their competitors' acceptance of such practices. Accordingly, the facilitating practice provides indirect proof of an "agreement."

Many facilitating practices exist, with varying degrees of success in promoting coordinated conduct.[183] Steven Salop identifies two distinct types: information exchange and incentive management.[184] Information exchange devices facilitate coordination by reducing uncertainty about competitors' actions and intentions.[185] For example, sharing information on actual sales and costs may enable competitors to determine whether a price reduction represents an instance of defection. Incentive management devices alter the structure of firms' pay-off matrices, thereby affecting their incentive to offer price discounts.[186] Meeting competition clauses illustrate this effect. Under meeting competition clauses, a firm announces that its price will not be higher than the lowest price posted by another firm.[187] Such clauses automatically incorporate the aggressive response to price-cutting—i.e., immediate price matching—needed to support coordination. Consumers are used to police the agreement, because the risk of missing out on the lowest price creates incentives for them to assume the costs of monitoring suppliers' conduct. These clauses may not be in consumers' interest if their collective acceptance stabilizes suppliers' joint profit outcomes and makes discounting less desirable.[188]

In today's digital world, there is less need for some information-exchange facilitating practices. Real-time data collection and rapid analysis make information exchange agreements redundant if relevant data can be easily collected through independent means. Still, other forms of information exchange may facilitate coordination, such as those pertaining to the kinds of datasets used by an algorithm, competitors' output and cost data, or the decisional parameters included in the algorithm.[189] With respect to incentive management devices, some may be even more potent in the digital world. Take, for example, meeting competition clauses, in which the online retailer promises consumers it will meet any lower price found on the Internet. If

183. Salop, *supra* note 176.
184. *Id.*
185. *Id.* at 272.
186. *Id.*
187. *Id.* at 280.
188. *Id.* at 273.
189. Reverse-engineering or backtracking logic can sometimes be used to determine such data without information exchange.

lower prices are immediately matched, competitors have no incentive to offer a discount.

2. Applications of the Concepts to Algorithms

Let us now relate the above concepts to algorithmic interactions. As will be shown, some concepts are as relevant as ever, while others are challenged by the digital world. The difficulty arises from the discord between existing conceptions and assumptions—shaped to apply to human interactions—and the way in which the digital world operates.

Some types of coordination between algorithms easily fall within the definition of agreement. A simple scenario involves the use of algorithms to implement, monitor, police, or strengthen a prior, explicit agreement among suppliers. In such situations, a clear agreement exists between the users of the algorithms, and the algorithms simply serve as the tools for their execution.[190] The case brought in 2015 by the U.S. Department of Justice against David Topkins for coordinating with other sellers the prices of posters sold online, illustrates such agreements. Topkins and his co-conspirators designed and shared dynamic pricing algorithms, which were programmed to act in conformity with their agreement.[191] The algorithms played a secondary role, based on an existing agreement between the sellers.[192] Such use of algorithms is not much different from a previously agreed upon price formula, even if the algorithm determines the final price based on such a formula, and takes into account data on market conditions inputted into it at any given time. FTC Commissioner Maureen Ohlhausen suggested a simple test that captures many of these easy cases: if the word "algorithm" can be replaced by the phrase "a guy named Bob," then algorithms can be dealt with in the same way as traditional agreements.[193]

The more difficult cases arise when algorithms are designed independently by market players to include decisional parameters that react to other players' decisions in a way which strengthens or maintains a joint coordinated outcome.[194] For example, a programmer might base the algorithm's decisional parameters on his predictions of the best responses to other players' conduct (an "expected coordination algorithm"). The algorithms explored in detail in the previous Section illustrate this case: They are designed and adopted

190. For four main scenarios, see EZRACHI & STUCKE, *supra* note 5.

191. Press Release, U.S. Dep't of Justice, Office of Pub. Affairs, Former E-Commerce Executive Charged with Price Fixing in the Antitrust Division's First Online Marketplace Prosecution (Apr. 6, 2015) [hereinafter Topkins Press Release].

192. *See id.*

193. *See* Ohlhausen, *supra* note 12.

194. *See* EZRACHI & STUCKE, *supra* note 5.

independently, without prior meetings or commitments, but each player independently codes his algorithm so that it takes into account other players' probable reactions, as well as their joint incentive to cooperate.[195] Even more difficult questions arise when algorithms are not deliberately designed in a way that facilitates coordination, yet they autonomously reach the same result. In these cases, the algorithm is given a general goal, such as "maximize profits," and it determines the decisional parameters it will use based on machine learning ("learned coordination").[196] While the question of who is legally liable for coordination may differ between the two scenarios, the two raise the same basic question of whether they reflect the existence of an agreement in the antitrust sense. I therefore explore whether such conduct constitutes (legal) conscious parallelism or (illegal) tacit agreement.

Let us start with the following suggestion: Conscious parallelism that results from algorithms simply mimicking human conduct, making the same decisions and taking the same actions as humans engaged in lawful conscious parallelism, without further facilitating coordination, should not constitute an agreement.[197] Any other rule would unjustifiably differentiate between algorithms and humans. The following example illustrates this point: assume a market in which longstanding conscious parallelism exists. Each of the firms operating in the market adopts an algorithm based on the benchmark for pricing that the firm has been using for years. Does the fact that market players are now using algorithms to achieve an identical result change the legal status of their conduct? If each supplier unilaterally and independently decides to adopt such an algorithm, and the algorithm does not significantly change their ability to reach and maintain the existing jointly profitable equilibrium, then it should not be regarded differently from the original method for decision-making, which was deemed to be legal.[198]

A tougher question arises when the algorithm uses similar decisional parameters and makes similar decisions to those made by humans under a given set of conditions, but in a much more efficient manner, thereby essentially facilitating coordination. Take, for example, the task of detecting price deviations and changing one's price accordingly. Algorithms can more easily perform this task than humans. Should their higher level of efficiency in performing this coordination-strengthening act change its legality? Put

195. *See* EZRACHI & STUCKE, *supra* note 5.

196. *Id.*

197. *See id.*; Harrington, *supra* note 6, at 32.

198. Harrington, *supra* note 6, at 45–46. Harrington suggests that some pricing algorithms that "condition play on a competitor's past prices" should be prohibited per se under section 5 of the Federal Trade Commission Act. Price matching algorithms would most likely fall under this prohibition. *See id.*

differently, can the employment of the algorithm be treated as a facilitating practice under existing law? The question arises because while the *pattern* of conduct is similar to what would otherwise be considered lawful, the *method* and *effect* of the conduct may differ significantly. As elaborated above, the use of algorithms may strengthen not only the ability, but also the incentives, to coordinate. Moreover, if the algorithm is transparent, it serves, by its nature, as a clear declaration about how the firm is going to react to market conditions, thereby changing the dynamics of the interaction.

Below I analyze the application to algorithmic interactions of some of the requirements, assumptions, and concepts on which antitrust law is based. As will be shown, while the use of algorithms is not prohibited, certain ways of using algorithms or other practices that in combination with algorithms facilitate coordination, may be considered illegal.

a) Application of Basic Concepts

Let us first examine the application to algorithmic interactions of fundamental concepts relating to agreements. This Section argues that the existing taxonomy is generally sufficiently broad as to capture such interactions. Note that at this stage I only explore whether an agreement was formed, not whether it is legal.

Engaging in an agreement requires the intent to do so.[199] Algorithms cannot have a mental state of "intent," or any mental state, for that matter.[200] Yet it might be claimed that algorithms intend to reach a certain goal by using a certain strategy, including reaching a coordinated equilibrium with other algorithms. If we do not wish to go so far, the intent of the programmer to create coordination through the use of algorithms, and the intent of the user to employ such an algorithm, can fulfill this requirement. This is because the algorithm serves as a tool for carrying out the intent of its programmer or user. Some cases are simple, such as the expected coordination scenario, in which the decision to include coordination-facilitating elements in the algorithm is a conscious one.[201] But this may not always be the case. Users may simply not be interested in the parameters which drive the algorithm's decisions. More interestingly, in the learned coordination scenario, the programmer might not be aware of such parameters if the algorithm is based on machine learning.[202] That is, instead of being specifically coded to react in a certain way, an

199. Courts often focus their analysis on the expressions made by one competitor to another, rather than on intentions. An expression of a willingness to enter into an agreement, even if the competitor had not intent of doing so, suffices. Algorithms can fulfill this requirement. In the European context, see Blockx, *supra* note 86.

200. Ezrachi & Stucke, *supra* note 47.

201. *See* Topkins Press Release, *supra* note 186.

202. *See* EZRACHI & STUCKE, *supra* note 5.

algorithm may be designed such that it independently determines the means to reach a given target through reinforced self-learning. Should the algorithm adopt a strategy that leads to conscious parallelism, coordination will not be the fruit of explicit human design but, rather, the outcome of evolution, self-learning, and independent machine execution.

Can we still find the resulting coordination to be the fruit of a conscious, avoidable act? To our mind, learning algorithms should generally not be treated differently from expert algorithms, which are specifically coded to react in certain ways. While this question deserves an extended analysis, five points are worth making. First, the algorithm's goals are set by its programmer.[203] Indeed, algorithms designed to serve the goals of a particular user act as software agents. These agents may navigate in a computerized network, while transmitting messages among themselves, and interacting with other agents, which might be controlled by other users. Second, algorithms learn from case studies supplied by the programmer and may be reinforced by the programmer's inputs.[204] Third, the programmer can place some limitations on the methods used by the algorithm to make his decisions. At the very least, so long as the algorithm's programmer can code it to *not* act in a certain manner, and incorporate safeguards that limit the scope of its reactions to market conditions (compliance by design), then any programmer's failure to do so should be taken into consideration. This can be likened to limitations placed on autonomous algorithms: self-driving cars should not be able to follow any and all possible decision paths to their logical conclusions simply because their algorithms are autonomous. Furthermore, the treatment of algorithms as a "black box" whose secrets are concealed even to the programmer is fallacious. As Avigdor Gal, Professor of Data Science at the Technion, argues, causal relations between the features (data points) used by an algorithm to reach its decision can be relatively easily observed by the programmer.[205] The programmer can thus be aware of such correlations, at least under certain circumstances. Learning algorithms can thus also be treated as conscious, avoidable acts. Note that this does not imply that such algorithms would necessarily create liability. This question is dealt with in the next Section.

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203. Simonetta Vezzoso, Competition by Design (June 15, 2017) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2986440 [https://perma.cc/WR9H-5RYG]; Emilio Calvano et al., *Algorithmic Pricing: What Implications for Competition Policy?* (July 7, 2018) (unpublished manuscript), https://ssrn.com/abstract=3209781 [https://perma.cc/3LUC-VGEV].

204. *See* P. Anitha, G. Krithka & Mani Deepak Choudhry, *Machine Learning Techniques for Learning Features of Any Kind of Data: A Case Study*, 3 INT'L J. ADVANCED RES. COMPUTER ENGINEERING & TECH. 4324, 4325.

205. *See, e.g.*, Gal, *supra* note 53.

Agreement requires a "meeting of minds."[206] Once again, in the expected coordination scenario, the presence or absence of a meeting of minds among the algorithms' programmers or users should determine the fulfillment of this requirement. The learned coordination scenario raises more difficult issues. An algorithm, operated by a computer, does not have a "mind" in the literal sense. Yet it makes decisions based on given inputs, including the expected and actual reactions of others. Moreover, as the studies surveyed above prove, algorithms can autonomously reach coordination which serves their goals.[207] Furthermore, Kaplow suggests that the term meeting of minds "readily covers . . . the standard scenario in which firms in an oligopoly are able to coordinate their prices by understanding each other's thought processes, which forms the basis for predicting their reactions to different prices that each firm may charge."[208] Should this definition be accepted, then it may include cases where algorithmic interactions lead to the conclusion that coordination is their best strategy, given the expected and actual reaction curves of competitors. Finally, the case law suggests that the mere exchange of commercially sensitive information to another party, which influences the action of the recipient, suffices.[209] Algorithms perform this function.

Can an algorithm communicate a conscious commitment to a common theme? Definitely yes. As elaborated above, a transparent algorithm can serve as a recipe for future action, including the price to be paid for deviations, which act as explicit threats of punishment.[210] Employing the algorithm in practice translates such a commitment into actions. While algorithms generally do not sign agreements, wink to each other, or nod their consent, they communicate through the decisional parameters coded into them. Other firms can then rely on such communications in order to shape their own actions.

In the non-algorithmic world, courts often look for evidence tending to show that the defendants "got together and exchanged assurances of common action."[211] Such physical meetings are, obviously, irrelevant to algorithmic interactions. Yet algorithms "get together" in cyberspace. They make use of

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206. *See, e.g.*, discussion in Kaplow, *supra* note 20. For a relatively similar issue in the European context, see, e.g., Andreas Heinemann & Aleksandra Gebicka, *Can Computers Form Cartels? About the Need for European Institutions to Revise the Concertation Doctrine in the Information Age*, 7 J. EUROPEAN COMPETITION L. & PRAC. 431 (2016).

207. *See* discussion on Page, *supra* note 17.

208. KAPLOW, *supra* note 20, at 34; *see* Jonathan B. Baker, *Two Sherman Act Section 1 Dilemmas: Parallel Pricing, the Oligopoly Problem, and Contemporary Economic Theory*, 38 ANTITRUST BULL. 143, 178 (1993).

209. AREEDA & HOVENKAMP, *supra* note 13.

210. For the role of explicit threats of punishment, see Page, *supra* note 17.

211. Page, *supra* note 17, at 603.

conditions in the digital world that enable them to observe and react to each other, and that make signaling, information transfer, and exchange of assurances easier.

Should the communication between parties be verbal? Some courts and scholars give weight to verbal communications in their definitions of agreement.[212] Yet it is generally agreed that intentional use of a well-understood nonverbal signal can express assent.[213] Conceptually, the requirement of communication is sufficiently wide as to include all forms of message delivery. Furthermore, mandating a certain kind of communication excludes cases in which competitors reach the same anticompetitive outcome through other means, which could be even more efficient. Accordingly, if exposing an algorithm's decisional parameters sends a signal to competitors, then this should be regarded as communication for legal purposes.

b) Algorithms as Plus Factors

Can the use of algorithms be treated as plus factors—which indirectly prove the existence of an agreement—once parallel conduct is proven to exist? For the answer to be affirmative, their use must constitute an intended and avoidable act that facilitates coordination by creating conscious commitments to a common scheme, which is not justified on procompetitive grounds.[214] Let us apply these conditions to algorithms.

As elaborated in Part II, the design and use of an algorithm is, in itself, an avoidable and intentional act.[215] Such algorithms can facilitate, maintain, or strengthen coordination by limiting incentives to compete beyond those that exist naturally.[216]

Several points are worth emphasizing with regard to the causal connection between the use of algorithms and coordination. First, not all algorithms facilitate coordination. Some may perform functions that do not affect the incentives or ability of firms to coordinate. Obviously, such algorithms should not be considered plus factors. Second, in determining the effects of an algorithm, it is important to separate any facilitating effects of using a given algorithm from facilitating effects that arise from the conditions of the digital world—e.g., increased connectivity. The latter should be taken as a given. Third, the use of algorithms is often combined with other practices that facilitate coordination. For example, a firm might design its website to continually display the price calculated by the algorithm. Or a firm may take

212. *Id.* at 614–16.
213. *Id.* at 605–06 and resources cited there.
214. *See supra* Section IV.A.1
215. *See supra* Part II.
216. *See supra* Part II.

measures designed to make the algorithm harder to change, thereby strengthening the degree to which competitors can rely on the algorithm's decisional process. All facilitating practices should be analyzed together. Fourth, it is useful to differentiate between algorithms that facilitate coordination among competitors, and those that might facilitate coordination among other market players. The algorithms used in the online posters case mentioned above illustrate the first case, while price comparison algorithms fall into the second category.[217] These two categories differ in both their economic functions and legal implications. While use of the former may be considered to constitute an agreement, the latter usually cannot.

Another question that arises is whether the adoption of facilitating practices must be uniform. The answer to this question should be negative. Assume, for example, that the algorithms do not employ similar decision trees, but the combination of their decisions nonetheless facilitates coordination. This may be the case when one competitor's algorithm sets a price at the jointly profitable level, and the others set prices based on that algorithm's price (a follower-leader scenario, like the algorithm presented above). In such a situation, requiring adoption of a similar algorithm by all competitors would make it easy to circumvent the requirement of "agreement." Therefore, there is no need for algorithms to be uniform, or for all competitors to employ algorithms, so long as each engages in conscious, avoidable acts that facilitate coordination.

The adoption of certain algorithms, followed by expected accommodating conduct by competitors, can therefore facilitate coordination and imply the existence of an implicit agreement. The problem with treating the adoption of algorithms as plus factors is, however, twofold. First, algorithms perform many functions in the digital environment, and bring about many benefits. Accordingly, if we cast the net too widely, we risk creating a chilling effect on welfare-enhancing conduct. While rules should not allow programmers and users to hide behind algorithms, they should also ensure that what we gain in limiting facilitating practices is greater than what we lose in limiting the range of allowable design choices. This does not imply that we should adopt a "hands off" approach to all algorithms, but rather, we must tread carefully. We should therefore ensure that our laws are based on an understanding of the role of algorithms in the marketplace, including their comparative advantages over human decision-making. In this respect, it makes sense to start with the easy cases in which harm to competition and welfare is more evident.

217. *See* Topkins Press Release, *supra* note 191; COMPETITION & MARKETS AUTHORITY, DIGITAL COMPARISON TOOLS MARKET STUDY (2017) (UK).

The second problem is the content of the prohibition: what exactly do we wish to prohibit, and can we spell this out clearly for market participants? Can we meaningfully instruct firms how to operate legally? To use Phillip Areeda's suggested rule of thumb: can we indicate, in less than twenty words, what kind of conduct firms are prohibited from engaging in?[218]

In light of the above, the algorithm's ability to facilitate coordination should be balanced against its pro-competitive effects. Algorithms should be subject to the following rule of reason analysis:

Diagram 1: Algorithms as facilitating practices

Does the algorithm facilitate or strengthen in a non-negligible way the ability to reach or maintain a jointly profitable market equilibrium?

no → **legal**

yes ↓

Is the use of the algorithm justified by neutral or procompetitive considerations?

no → **illegal**

yes ↓

Do these considerations outweigh the algorithm's coordination-facilitating effects, and are the latter needed in order to enjoy the former?

no → **illegal**

yes → **legal**

Observe that it should not be necessary for an algorithm to have no potential procompetitive effects—only that the balance should not be tilted toward their anticompetitive outcomes. Otherwise, we might not capture any algorithms under our laws, given that they often create efficiencies.[219] Furthermore, as Kaplow argues, in determining whether a possibly ambiguous practice should be viewed positively or negatively, it is necessary to consider the real effects on the market.[220] If, for example, transparency makes it easier for sellers to identify cheaters and deter defection, then buyers will simply gain better information about high supra-competitive offers.[221] At the same time, it is important to also give weight to wide institutional considerations in order to

218. Thanks to Bill Kovacic for suggesting the use of this test.
219. *See* Mehra, *supra* note 5.
220. KAPLOW, *supra* note 20, at 279.
221. *Id.* at 279.

ensure that we do not chill efficiency and innovation. This implies that considerations such as creating ex ante certainty should also be weighed.

Importantly, algorithms should not necessarily be treated as indivisible units. Indeed, the facilitating device may form only part of the algorithm. It is often the case that an algorithm performs many functions, such as gathering the data, analyzing it, and determining what trade terms to set based on the data.[222] Many of these functions can be welfare-enhancing, reducing costs or increasing the quality of production or marketing functions, and therefore should be allowed.[223] At the same time, some functions may be used to facilitate coordination. It is thus essential to separate the different functions and determine whether the benefits of the former are dependent on the harms of the latter. Otherwise we risk throwing out the baby with the bathwater. This suggestion also serves as a partial answer to those who are concerned that regulating algorithms would limit the benefits they bring about.

This leads to a third suggestion: because our understanding of how algorithms interact in the digital world is still rudimentary, the rules regulating algorithms should be developed in widening circles, in keeping with our understanding of their potential effects on the market and the potential chilling effects of overbroad prohibition. Accordingly, as a first step, competition authorities should strive to identify the relatively straightforward cases in which the legal requirements can be easily applied and a relatively clear rule can be created.

Below I suggest five cases which raise red flags and therefore are good candidates for a repository of cases characterized by prima facie justification for further examining their legality. All cases share three traits: (1) they may facilitate coordinated conduct; (2) they are potentially avoidable by the algorithm's programmers or users; and (3) they are unlikely to be necessary in order to achieve procompetitive results. Such practices may thus amount to "coordination by design." The cases are as follows:

1. Suppliers consciously use **similar algorithms even when better algorithms are available to them**. The algorithms need not be identical, but their operative part—which calculates the trade conditions—should generate relatively similar outcomes.

Observe that the use of similar algorithms, by itself, is insufficient to lead to a coordinated outcome. This can be illustrated by a simple example: assume that all algorithms base the price on their firm's production costs. If

222. *See* Org. for Econ. Co-operation & Dev., *Algorithms and Collusion – Background Note by the Secretariat*, OECD Doc. DAF/COMP(2017)4 9–16 (June 6, 2017).

223. *See id.*

production costs differ among competitors, the algorithms will not lead to a jointly profitable price.

2. Firms make conscious use of **similar data** on relevant market conditions **even when better data sources exist.** Data is an essential input in the decision-making process, which affects the decision. Using similar data is especially important when prices are based on consumers' digital profiles. Note that the data sources themselves need not be identical so long as the information gleaned from them is relatively similar.

3. Programmers or users of learning algorithms give them **similar case studies** from which to learn **despite those not being the best-case studies readily available**. Learning algorithms change their decision trees based on learning from past experience. If fed similar cases, the algorithms may learn similar things and make decisions accordingly.

4. Users take actions that make it **easier for their competitors to observe their algorithms and/or their databases**, and their competitors take actions to observe them. The algorithm can signal to other market players how its user is likely to react to market conditions, thereby communicating intent and possibly a credible commitment.[224] The easiest case arises, of course, when the algorithm is revealed only to one's competitors (either by allowing them to digitally access it or by sending it to them privately). For example, the algorithm might encrypt its information so that only competitors can read it. In such cases it is clear that the algorithm's transparency does not serve consumers, and is artificial rather than an inherent part of digital markets. But even when the algorithm or database is revealed to all, such an action might still amount to a plus factor or a facilitating practice, depending on the circumstances. Those include, inter alia, the following: (1) does such transparency benefit consumers in any significant way; (2) do consumers have the means and incentives to understand the operation of the algorithm; and (3) does the competitor otherwise have incentives to keep the content of the algorithm or the database a trade secret. This category fits well with the current prohibition against the exchange of competitively sensitive information among competitors in an effort to stabilize or control industry pricing.[225]

224. *See* Harrington, *supra* note 6, at 45.
225. *See* Ohlhausen, *supra* note 12.

5. The user technologically **“locks” the algorithm** so that it is difficult to change it. This creates a long-term commitment, or a credible threat that can strengthen coordination, generally without a procompetitive justification.

In all these cases, firms communicate their intentions to act in a certain way, as well as their reliance on one another to follow suit. They do so by using avoidable acts that lack a competitive rationale but that facilitate coordination. Acts that fall under any of these categories in markets, where supra-competitive parallel pricing is observed, should raise red flags and trigger a deeper investigation into procompetitive justifications. The remedy is clear and easy to apply. Of course, when only one side takes action, the conduct might not amount to an agreement in restraint of trade, but rather to an attempt for such an agreement.

Enforcement is likely to become an up-hill battle. Indeed, as the Google Brain experiment noted above indicates, detection and enforcement will become much harder once algorithms autonomously encrypt their messages.[226] Accordingly, antitrust authorities may need to strengthen their technological expertise by employing regulatory algorithms or computer scientists. Nonetheless, several features of algorithms may make such regulatory tasks easier. Algorithms’ decision trees reveal the considerations taken into account in reaching decisions.[227] Moreover, algorithms can be tested by running them on specific data, thereby indirectly exposing their decisional parameters.[228] Finally, algorithms can be used by regulators to police and understand the operations of other algorithms.[229] For example, they can be used to determine whether, absent transparency of one’s competitors’ algorithms, the market equilibrium would have been set at such a high level. By using their resources, authorities can further identify cases which raise red flags, which are based on understanding how algorithms work in the digital environment.

B. THE WAY FORWARD: WIDENING THE NET

The above discussion remains within the confound of existing conceptions of “agreement.” While it explored the width of existing laws to capture some

226. FTC Commissioner McSweeny also recognized the increased detection challenges created by algorithms. Terrell McSweeny, Former Comm’r, Fed. Trade Comm’n, Remarks at Univerisity of Oxford Center for Competition Law and Policy: Algorithms and Coordinated Effects (May 22, 2017).

227. *See Decision Tree*, WIKIPEDIA, https://en.wikipedia.org/wiki/Decision_tree [https://perma.cc/X2NN-KUST].

228. *See* EZRACHI & STUCKE, *supra* note 5.

229. *See* Gal, *supra* note 53, at 6.

types of algorithmic-facilitated coordination, using existing laws to deal with algorithmic-facilitated coordination is not a panacea. Most importantly, as Antonio Capobianco and Anita Nvesto from the Organization of Economic Cooperation and Developmemt observed, "[o]ne of the main risks of algorithms is that they expand the grey area between unlawful explicit collusion and lawful tacit collusion, allowing firms to sustain profits above the competitive level more easily without necessarily having to enter into an agreement."[230] Indeed, as the above analysis showed, the risk of increased conscious parallelism, facilitated by algorithms, is likely to increase. While coordination is not inevitable, sustaining such coordination is strengthened by the inherent characteristics of digital markets and by the increased abilities of algorithms, often without a need to recourse to formal communication or agreement. The use of an algorithm to solve a complex joint profit-maximizing objective that will produce immediate results, and could be followed by others in the market, might not be captured under existing laws. More fundamentally, the fact that algorithms act as "recipes for action" create a situation that is likened to explicit communication.[231] Yet the fact that the algorithm can sometimes be observed indirectly (through reverse-engineering of its actions), limits the ability to capture it under current prohibitions.

Accordingly, unless we treat every algorithm that helps facilitate coordination as a plus factor—a suggestion which is highly problematic—current interpretation of the term "agreement" is likely to leave out many welfare-reducing instances. While the use of autonomous algorithmic interactions to set trade terms has not yet become mainstream, firms have strong incentives to do so. If algorithms can determine trade terms better than humans, and the resulting coordination might be considered legal, there is a strong motivation to use them.

Accordingly, there is an urgent need for a renewed discussion of whether and how current laws should be changed to fit a world that has dispensed with the need for meetings, conversations, and price announcements. The importance of such an analysis is based on the findings of this Article. First, instances of coordination through algorithms are likely to become more commonplace in our digital world.[232] This also implies that one of the considerations underlying the rule which treats conscious parallelism as legal—that it can take place only in a limited number of highly concentrated markets and is therefore likely to create minor economic effects—no longer holds.

230. Antonio Capobianco & Anita Nyeso, *Challenges for Competition Law Enforcement and Policy in the Digital Economy*, 9 J. EUROPEAN COMPETITION L. & PRAC. 19, 25 (2017).

231. Salcedo, *supra* note 5; Schwalbe, *supra* note 5, at 16.

232. *See supra* Part II.

Second, current rules were designed to fit a world characterized by inherent limitations on the human capacity to reach coordination.[233] As the digital world increasingly overcomes these limitations, making it easier to reach agreements, monitor compliance, and apply immediate sanctions, the law will axiomatically capture fewer instances of coordination than it did before. Furthermore, the digital world increases the "paradox of proof," in that market conditions make it easier to coordinate, and at the same time make it more difficult to prove the existence of an explicit agreement given that explicit interfirm communication may be less essential.[234] This suggests that, while the danger of harm might increase, it might also be less likely to find strong evidentiary inferences of an agreement.[235] It is thus the time to rethink our laws and focus on reducing harms to social welfare rather than on what constitutes an agreement. There may well be a case for not binding ourselves to past formulations which no longer fit economic realities.[236] In particular, the time may be ripe to reconsider prohibiting any conduct with potential anticompetitive tendencies with no offsetting pro-competitive ones, even where such conduct does not constitute an agreement in the traditional sense.

V. CONCLUSION

The new world in which algorithms make many business decisions challenges some of our most basic assumptions about how markets operate. As shown, algorithms can make coordination easier and quicker than ever, thereby reducing incentives to compete. This in turn, increases the importance of tools to curtail potential welfare-reducing effects, while ensuring that consumers can enjoy the benefits offered by the digital world. This Article explored some of the challenges to competition created by algorithms used by competitors, as well as some potential market-based and legal countermeasures. In particular, it explored the application of the legal constructs of facilitating practices and plus factors to algorithms, and it suggested a subset of cases which fall under existing rules. As shown, existing laws can capture some of the cases in which algorithms facilitate coordination, yet significant challenges remain.

We are already playing catch-up with technological developments in the use of algorithms and will likely continue to do so. But given the welfare stakes

233. *See supra* Part III.

234. *See* KAPLOW, *supra* note 20, at 124–73.

235. *See id.* at 305.

236. One such interesting suggestion was made by Harrington, *supra* note 6, at 48–49 (suggesting that some types of pricing algorithms that support supra-competitive prices be per se prohibited, such as reinforcement learning price setting algorithms).

involved, our only option is to brace ourselves for the road ahead and make sure we are as prepared as possible. As one court noted, "the advancement of technological means for the orchestration of large-scale price-fixing conspiracies need not leave antitrust law behind."[237] This Article takes a step in this direction.

237. Spencer Meyer et al., v. Travis Kalanik, 2016 WL 1266801 15 Civ. 9796 (District Court, S.D. New York, March 31, 2016), Section 7.