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Cover Page Footnote

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ABSTRACT—Algorithmic collusion has the potential to transform future markets, leading to higher prices and consumer harm. And yet, algorithmic collusion may remain undetected and unchallenged, in particular, when it is used to facilitate conscious parallelism. The risks posed by such undetected collusion have been debated within antitrust circles in Europe, the US, and beyond. Some economists, however, downplay algorithmic tacit collusion as unlikely, if not impossible. "Keep calm and carry on," they argue, as future prices will remain competitive. This paper explores the rise of algorithmic tacit collusion and responds to those who downplay it, by pointing to new emerging evidence and the gap between law and this particular economic theory. We explain why algorithmic tacit collusion is not only possible but warrants the increasing concerns of many enforcers.

Keywords: Competition law, Antitrust, Algorithms, Algorithmic Tacit Collusion, Hub and Spoke
JEL Classification: D43, D50, D81, K21, L1, L13, L16, O30

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We are grateful for comments received from participants in the 2017 Organization for Economic Co-operation and Development [OECD] roundtable on "Algorithms and Collusion" and the 2018 Max Planck Round Table Discussion on Tacit Collusion.

INTRODUCTION

As one law firm noted in 2018, "[p]rice algorithms are clearly the 'talk of the town' in the European competition law community these days."[1] During the summer of 2018, the law firm noted,

> [B]oth the Federal Cartel Office and the Austrian Federal Competition Authority have addressed the question of whether the use of price algorithms can lead to excessive ticket prices in the airline industry. . . . [T]he French Autorité de la Concurrence and the Federal Cartel Office announced the launch of a joint research project to investigate algorithms and their implications on competition.[2]

The European Commission is seeking input on these issues, as well.[3] The German Monopolies Commission, in its 2018 report, recommended the government "to systematically investigate markets with algorithm-based pricing for adverse effects on competition."[4] Among the key concerns raised are pricing algorithms that help competitors elude detection for their price-fixing or algorithms that – with or without the help of humans – tacitly collude. With tacit collusion (also known as, "conscious parallelism"), there is not any illegal agreement or even any contact or communication among the competitors. Instead, each competitor acts unilaterally, in response to the behavior of its rivals, to raise price above competitive levels.

In our earlier writing, we outlined four key scenarios where algorithms may be used to facilitate collusion,[5] and in 2016, we provided further context and analysis in our book, *Virtual Competition: The Promise*

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[1] Christian Ritz & Lorenz Marx, *Digital Competition Policy on the Move: Price Algorithms in the German Monopolies Commission's Spotlight – European Commission Launches Consultation Process*, HOGAN LOVELLS: FOCUS ON REGULATION (July 11, 2018), https://www.hlregulation.com/2018/07/11/digital-competition-policy-on-the-move-price-algorithms-in-the-german-monopolies-commissions-spotlight-european-commission-launches-consultation-process/ [https://perma.cc/HRG8-28ZN].

[2] *Id*.

[3] *See* Jean Tirole, *Shaping Competition Policy in the Era of Digitization*, EUR. COMM'N (Jan. 17, 2019), https://webcast.ec.europa.eu/shaping-competition-policy-in-the-era-of-digitisation [https://perma.cc/ZSL6-CXQP] (advance video to 03:30:27).

[4] Press Release, Monopolkommission [German Monopolies Commission], *Digital Change Requires Legal Adjustments Regarding Price Algorithms, The Media Sector and the Supply of Medicines*, MONOPOLIES COMM'N (July 3, 2018), https://www.monopolkommission.de/images/HG22/PM_HG_2018_EN.pdf [https://perma.cc/QW5S-UB8Z].

[5] Ariel Ezrachi & Maurice E. Stucke, *Artificial Intelligence & Collusion: When Computers Inhibit Competition*, 2017 U. ILL. L. REV. 1775, 1782-84 (2017); *see also* Ariel Ezrachi & Maurice E. Stucke, *Emerging Antitrust Threats and Enforcement Actions in the Online World*, 13 COMPETITION L. INT'L 125, 129 (2017).

and Perils of the Algorithm-Driven Economy.[6] Finally, we engaged in further thematic development in our submissions to the U.K. House of Lords[7] and OECD,[8] and testimony at the Federal Trade Commission hearings on algorithmic collusion.[9]

Broadly, we have gleaned general consensus over our first two scenarios: *Messenger*, where humans agree to collude by fixing the price for their competing products and use algorithms to facilitate their collusion; [10] and *Hub and Spoke*, where a common intermediary facilitates price-fixing among competitors who use the intermediary's services.[11] Indeed, the European Commission and United States antitrust authorities, among others, raised concerns that algorithms could facilitate collusion[12] and have

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[6] ARIEL EZRACHI & MAURICE E. STUCKE, VIRTUAL COMPETITION: THE PROMISE AND PERILS OF THE ALGORITHM-DRIVEN ECONOMY (2016).

[7] Written evidence from Professor Ariel Ezrachi and Professor Maurice E. Stucke Submitted to Select Committee on European Union Internal Market Subcommittee, *Online Platforms and the EU Digital Single Market*, U.K. PARLIAMENT (Oct. 16, 2015), http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/eu-internal-market-subcommittee/online-platforms-and-the-eu-digital-single-market/written/23223.html [https://perma.cc/6NDQ-TEVF]; SELECT COMMITTEE ON EUROPEAN UNION, ONLINE PLATFORMS AND THE DIGITAL SINGLE MARKET, 2015-16, HL 129 *passim* (UK).

[8] Note by Ariel Ezrachi & Maurice E. Stucke*, Algorithmic Collusion: Problems and Counter-Measures*, OECD Doc. DAF/COMP/WD(2017)25 (May 31, 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)25/en/pdf [https://perma.cc/53AY-V74Y].

[9] *Transcript of FTC Hearings Session No. 7: Competition and Consumer Protection in the 21st Century - Day 2*, U.S. FED. TRADE COMM'N 19-84 (Nov. 14, 2018), https://www.ftc.gov/system/files/documents/public_events/1418693/ftc_hearings_session_7_transcript_day_2_11-14-18_0.pdf [https://perma.cc/5V8Y-NQXA].

[10] Here humans agree to collude and turn to pricing algorithms to help implement their cartel. The commonly programmed algorithm can reduce the incentives of cartel members to deviate and thereby contribute to the cartel's stability, by implementing the agreed upon price, improving the detection of any cheating from this price, and enabling the other cartel members' algorithms to quickly retaliate by matching or lowering price. From an enforcement perspective, the law is straight-forward, but the agency's detection of the cartel may be harder, when the use of similar pricing algorithms reduces the need of humans to regularly communicate to monitor their cartel.

[11] At times, a seller may outsource its ongoing dynamic pricing adjustments to a third party whose advanced algorithms continually process market data to update prices and optimize profits. Such agreements enable a seller that lacks the algorithms and market data to benefit from dynamic pricing. When competitors increasingly use the same third-party pricing algorithm, one company, the "hub," can materially impact the industry price and dampen competition. *See* Opinion of Advocate General Szpunar delivered on 11 May 2017, Case C-434/15, Asociación Profesional Elite Taxi v. Uber Systems Spain SL, ECLI:EU:C:2017:364, at 13 n. 23 (noting that "the use by competitors of the same algorithm to calculate the price is not in itself unlawful, but might give rise to hub-and-spoke conspiracy concerns when the power of the platform increases"); *see also* Meyer v. Kalanick, 174 F. Supp. 3d 817, 822-27 (S.D.N.Y. 2016) (finding that plaintiffs plausibly alleged a hub-and-spoke conspiracy in which drivers sign up for Uber precisely on the understanding that the other drivers were agreeing to the same pricing algorithm, and in which drivers' agreements with Uber would be against their own interests were they acting independently), *reconsideration denied in part*, 185 F. Supp. 3d 448 (S.D.N.Y. 2016).

[12] Note from the European Union*, Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)12, at 7 (June 14, 2017), https://one.oecd.org/document/DAF/COMP/WD

opened investigations on these scenarios.[13] Most policy makers recognize how "pricing algorithms may make price fixing attempts more frequent and potentially more difficult to detect."[14] Most say "with confidence . . . that the rise of pricing algorithms and AI software will require changes in our enforcement practices;" and most would agree that enforcers "need to understand how algorithms and AI software work in particular markets."[15]

What has sparked debate, however, are our third and fourth scenarios, namely *Tacit Collusion on Steroids* – where humans program their pricing algorithms to monitor and respond to rivals' pricing and other keys terms of sale, and they know that the likely outcome will be conscious parallelism and higher prices (without the need of the rivals to communicate with each other or otherwise enter into an illegal cartel agreement), and *Artificial Intelligence and the Digital Eye* – where we predict that advances in machine learning and increases in market transparency may eventually enable self-learning algorithms to unilaterally determine the profit-maximizing price. Under the right market conditions, the self-learning algorithms may independently arrive at tacit collusion, without the knowledge or intent of their human programmers.

(2017)12/en/pdf [https://perma.cc/9CCF-S72G]; Note by United States, *Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)41, at 6 (May 26, 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)41/en/pdf [https://perma.cc/8U89-NJL8] ("[I]f competing firms each entered into separate agreements with a single firm (for instance a platform) to use a particular pricing algorithm, and the evidence showed they did so with the common understanding that all of the other competitors would use the identical algorithm, that evidence could be used to prove an agreement among the competitors that violates U.S. antitrust law."). But if the competitors independently and unknowingly adopted the same or similar pricing algorithms, this would "unlikely to lead to antitrust liability even if it makes interdependent pricing more likely." *Id.* An interesting issue is whether the competitors would be liable if they intentionally but unilaterally adopted the same algorithm knowing that this would make interdependent pricing more likely.

[13] *See, e.g.*, Daniel Mandrescu, *When Algorithmic Pricing Meets Concerted Practices- the Case of Partneo*, CORE BLOG (June 7, 2018), http://coreblog.lexxion.eu/when-algorithmic-pricing-meets-concerted-practices-the-case-of-partneo/ [https://perma.cc/H6LS-NFFF] (discussing the car makers' use of Accenture's car part pricing algorithm, Partneo, which was "designed to identify the maximum price consumers would be willing to pay for (visible) cars parts such as fenders or bumpers where there is almost no inter or intra brand competition" and how during the period of 2008 to 2013 the five major carmakers "boosted their revenues by more than 1 billion dollars thanks to using Partneo, which increased the prices of their inventory with 15% on average"); Tom Bergin & Laurence Frost, *RPT-INSIGHT-Software and Stealth: How Carmakers Hike Spare Parts Prices*, REUTERS (June 4, 2018, 1:02 AM), https://www.reuters.com/article/autos-software-pricing/rpt-insight-software-and-stealth-how-carmakers-hike-spare-parts-prices-idUSL5N1T60H9 [https://perma.cc/HTU6-DFZV]. No formal findings, however, have been found against the carmakers or Accenture.

[14] Terrell McSweeny, Comm'r, U.S. Fed. Trade Comm'n, *Algorithms and Coordinated Effects*, Remarks at U. Oxford Ctr. for Competition L. Pol'y, U.S. FEDERAL TRADE COMM'N (May 22, 2017), https://www.ftc.gov/system/files/documents/public_statements/1220673/mcsweeny_-_oxford_cclp_remarks_-_algorithms_and_coordinated_effects_5-22-17.pdf [https://perma.cc/D2RN-T969].

[15] *Id.*

These two categories raise significant policy issues, as they suggest that in the future, pricing algorithms may facilitate higher (supra-competitive) prices, without triggering antitrust intervention. Furthermore, such algorithmic tacit collusion can arise in markets where such tacit collusion previously among humans would have been unstable. As we elaborate below, the possible use of algorithms for price coordination, below the antitrust radar screen, raises challenging policy questions. Among them:

- Should our current antitrust policy towards conscious parallelism (which was designed based on human interaction) apply when price optimization algorithms enhance the competitors' ability to tacitly collude?
- Is the legal concept of agreement outdated for computer algorithms? Are our current antitrust laws sufficient to deter and prevent algorithmic tacit collusion?
- How can the agencies identify when algorithmic collusion occurs, especially when pricing is dynamic?
- What additional measures should be considered to reduce the additional risks associated with the industry-wide use of price optimization algorithms?
- In what way should firms be obligated to integrate ethics and legality into a computer program?
- Should companies have an affirmative duty to program the computers so as to not tacitly collude?

While competition agencies and international organizations have debated these challenging questions, some have argued that the issue is moot. Several economists put forward the claim that the likelihood, in practice, of tacit collusion in either the brick-and-mortar economy or digital economy, is minimal. They argue that algorithmic tacit collusion should not pose any concern because collusion is unsustainable without supporting communications between humans.[16] According to this view, tacit collusion with three or more rivals - whether by algorithms or humans - is unlikely,

[16] Ulrich Schwalbe, *Algorithms, Machine Learning, and Collusion*, 14 J. COMPETITION L. ECON. 568, 600 (2019); Thibault Schrepel, *Here's Why Algorithms Are NOT (Really) A Thing*, CONCURRENTIALISTE (May 15, 2017), https://leconcurrentialiste.com/2017/05/15/algorithms-based-practices-antitrust/ [https://perma.cc/P4CX-XVK8]; Kai-uwe Kühn & Steve Tadelis, *Algorithm Collusion,* CRESSE (2017), http://www.cresse.info/uploadfiles/2017_sps5_pr2.pdf [https://perma.cc/Y2G5-5A4K]; *Transcript of FTC Hearings Session No. 7: Competition and Consumer Protection in the 21st Century - Day 1*, U.S. FED. TRADE COMM'N (Nov. 13, 2018), https://www.ftc.gov/system/files/documents/public_events/1418693/ftc_hearings_session_7_transcript_day_1_11-13-18_0.pdf [https://perma.cc/EZZ8-BRYX]; *Transcript of FTC Hearings Session No. 7: Competition and Consumer Protection in the 21st Century - Day 2, supra* note 9.

as the "coordination problems are hard to solve without communication, even in simple static games."[17] These communications, the argument goes, can be captured under current antitrust laws such as Article 101 of the Treaty on the Functioning of the European Union (TFEU) – and US antitrust provision – Section 1 of the Sherman Act. And so, because pricing algorithms cannot tacitly collude without rivals actually communicating with each other, the antitrust laws would capture these communications among humans, and thus the current antitrust tools would suffice for the digital economy.

In this paper, we elaborate on the phenomenon of algorithmic tacit collusion and consider it in light of the claim that, in practice, such collusion is unlikely without communications. We note how this claim has not slowed the enforcers' interest and momentum to tackle the policy issues underlying algorithmic tacit collusion.

In Part I, we outline the theory and the way pricing algorithms, in specific market conditions, may foster tacit collusion (also referred to as conscious parallelism or oligopolistic price coordination).

In Part II, we tackle the instability of tacit collusion. We consider the claim that absent some human communication, tacit collusion is inherently unsustainable. This belief is based on experimental economics and the difficulty of sustaining tacit collusion under certain laboratory conditions. According to this view, the model of tacit collusion will rarely manifest itself in the real world without some supporting communication.

We explain how the economic observations at the core of this claim diverge from antitrust law and enforcement policies. When observing the market reality, courts and enforcers on both sides of the Atlantic have seen, in the brick-and-mortar economy, durable tacit collusion that seemingly occurs without any human communication between rivals. Basically, competitors, watching each other like hawks, steadily raise their prices above competitive levels. Because this durable tacit collusion can occur without any human communication, the courts require from the enforcer or private plaintiff proof of express collusion, namely, sufficient direct or circumstantial evidence of an agreement or illicit communication among the competitors. Absent this evidence, the courts say that the rivals' parallel behavior is legal. Because the conduct is otherwise legal, the primary mechanism to prevent tacit collusion is merger review.[18] To put it simply,

[17] *See* Kühn & Tadelis, *supra* note 16; *see also* Schwalbe, *supra* note 16, at 592.

[18] As we discuss *infra* in Part II, enforcers, when appraising proposed acquisitions, may block mergers that significantly increase the risk of tacit collusion. They expect "industry awareness" would allow rivals to engage in conscious parallelism post-merger without the need of any illicit communications.

enforcers and antitrust plaintiffs search hard for evidence of express collusion and communication, but these parties and courts ultimately recognize that anticompetitive parallel behavior can arise without communications among the rivals, and thus, comfortably occur within the zone of legality. Indeed, this parallel behavior among competitors happens with sufficient frequency that neither the EU nor US law presume any illicit communication.

Part III addresses the debate as to the added risk offered by algorithms (without express communication). We note how humans may program algorithms to reflect the logic behind conscious parallelism - punish deviations and follow price increases. We note how the use of similar algorithms by competitors and the ability to identify the strategy employed by others, may further stabilize conscious parallelism. Importantly, we explain that when executed carefully, and absent illicit communication, these unilateral strategies would not trigger antitrust intervention under current laws.

As part of this discussion, we also consider possible future technologies and the capacity of self-learning algorithms to adopt a strategy, which may lead to price increases (absent illegal collusion). The question here is whether in some future markets, tacit collusion could be sustained without human intervention.

In Part IV we offer policy makers tools to better understand the risks of algorithmic tacit collusion. Interestingly, some scholars, taking up our suggestion to develop algorithmic tacit collusion incubators, are doing just that, and we report some of their recent findings. While still in the early stages of research, their findings, which illustrate the possibility for algorithmic tacit collusion, suggest that competition authorities have reasonable grounds for their concerns.

This issue is both timely and important. If an antitrust agency accepts the view that tacit collusion is impossible without human communication, then it need not worry about algorithms tacitly colluding. This can play out two ways. First, rather than keep a close eye on these technological developments and consider potential policy responses, the enforcer would, as some urge, do nothing. It will not develop algorithmic tacit collusion incubators or conduct market inquiries. It will not even distinguish between legitimate human tacit collusion and enhanced algorithmic tacit collusion, nor would it consider what forms of enhancement may be caught as facilitating practices or signaling, or which action may qualify as

collusion.[19] In short, the agency would continue with its leniency program for price fixers[20] and sniff out cases where humans still conspire.

Second, the agency's merger review will remain incomplete, as it will not appreciate the increased likelihood for tacit collusion in industries dominated by pricing algorithms. At present, agencies lack good predictive models of when a merger significantly increases the likelihood of tacit or express collusion. As one economist explained it to the entering Honors Program lawyers at the US Department of Justice Antitrust Division in the mid 1990s, "*the merger occurs and s*** happens.*" Not surprisingly, merger review in recent decades has primarily focused on unilateral effects, which are relatively easier to model and estimate.[21] However, as more markets become more concentrated and more susceptible to tacit collusion, the harm from ignoring (or downplaying) this risk in merger review increases.

I. ALGORITHMIC TACIT COLLUSION – THE BASE CONDITIONS

Let us first consider the general consensus on tacit collusion. Everyone agrees that it is a challenging area for antitrust enforcement, as it leads to an anticompetitive outcome (namely, higher prices, reduced output, or allocated markets) without any illegal agreement among competitors.[22] As the OECD noted, "Although there is great variance in how jurisdictions interpret the notion of agreement, they traditionally require some sort of proof of direct or indirect contact showing that firms

[19] Joseph E. Harrington Jr, *Developing Competition Law for Collusion by Autonomous Price-Setting Agents*, 14 J. COMPETITION L. & ECON. 331 (2018).

[20] *See generally Corporate Leniency Policy*, U.S. DEP'T OF JUSTICE, https://www.justice.gov/atr/corporate-leniency-policy [https://perma.cc/DSU8-MR9V].

[21] *See, e.g.*, Malcolm B. Coate, The Merger Review Process in the Federal Trade Commission from 1989 to 2016 (Feb. 28, 2018) (unpublished working paper), https://ssrn.com/abstract=2955987 [https://perma.cc/A9QS-VLK8] (identifying for FTC mergers a trend toward unilateral effects analysis and increase in efficiency findings after 1994, although dropping for challenged mergers after 2004).

[22] *See, e.g.*, Background Note by the Secretariat, *Algorithms and Collusion,* OECD Doc. DAF/COMP(2017)4, at 17 (June 9, 2017), https://one.oecd.org/document/DAF/COMP(2017)4/en/pdf [https://perma.cc/29VF-2RFT] (noting that tacit collusion "refers to forms of anti-competitive co-ordination which can be achieved without any need for an explicit agreement, but which competitors are able to maintain by recognising their mutual interdependence. In a tacitly collusive context, the non-competitive outcome is achieved by each participant deciding its own profit-maximising strategy independently of its competitors"); Brooke Grp. Ltd. v. Brown & Williamson Tobacco Corp., 509 U.S. 209, 227 (1993) (describing "the process, not in itself unlawful, by which firms in a concentrated market might in effect share monopoly power, setting their prices at a profit-maximizing, supracompetitive level by recognizing their shared economic interests and their interdependence with respect to price and output decisions" and subsequently unilaterally set their prices above the competitive level); *Glossary of Industrial Organisation Economics and Competition Law*, OECD (1993), http://www.oecd.org/dataoecd/8/61/2376087.pdf [https://perma.cc/ZF68-G4N5].

have not acted independently from each other (the so-called, 'meeting of the minds')."[23]

tacit collusion has taken another dimension with the proliferation of pricing algorithms. Many competition authorities recognize the risk that algorithms can facilitate and enhance tacit collusion. The OECD in 2016, for example, commented that these "strategies may pose serious challenges to competition authorities in the future, as it may be very difficult, if not impossible, to prove an intention to coordinate prices, at least using current antitrust tools."[24] With the industry-wide use of computer algorithms and artificial intelligence, the concern is that algorithmic tacit collusion can arise in markets where such collusion previously would have been unstable. The OECD in 2017 reached the following two conclusions:

> Firstly, algorithms are fundamentally affecting market conditions, resulting in high price transparency and high-frequency trading that allows companies to react fast and aggressively. These changes in digital markets, if taken to a certain extent, could make collusive strategies stable in virtually any market structure. Secondly, by providing companies with powerful automated mechanisms to monitor prices, implement common policies, send market signals or optimise joint profits with deep learning techniques, algorithms might enable firms to achieve the same outcomes of traditional hard core cartels through tacit collusion.[25]

Similar concerns as to the possible use of algorithms to sustain tacit collusion have been raised by policy makers and competition agencies (among them, Germany, Italy, France, United Kingdom, Russia, Israel, and Australia).[26]

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[23] Background Note by the Secretariat, *supra* note 22, at 17.

[24] Ania Thiemann & Pedro Gonzaga, OECD Competition Div., Background Note by the Secretariat, *Big Data: Bringing Competition Policy to the Digital Era*, OECD Doc. DAF/COMP(2016)14 (Oct. 27, 2016), https://one.oecd.org/document/DAF/COMP(2016)14/en/pdf [https://perma.cc/KL28-QS5D].

[25] Background Note by the Secretariat, *supra* note 22, at 49-50.

[26] *See e.g.,* Antonio Capobianco et al., OECD, *Algorithms and Collusion: Competition Policy in the Digital Age*, OECD (2017), http://www.oecd.org/daf/competition/Algorithms-and-colllusion-competition-policy-in-the-digital-age.pdf [https://perma.cc/KJ2C-AEZQ]; Press Release, Monopolkommission, *supra* note 4; Press Release, Autorité de la Concurrence [French Competition Authority] & Bundeskartellamt [German Federal Cartel Office], *The French Autorité de la Concurrence and the German Bundeskartellamt Launch A Joint Project on Algorithms and Their Implications on Competition*, BUNDESKARTELLAMT (Jun. 19, 2018) (Fr. & Ger.), https://www.bundeskartellamt.de/SharedDocs/Publikation/EN/Pressemitteilungen/2018/19_06_2018_Algorithmen.pdf?__blob=publicationFile&v=2 [https://perma.cc/V7GL-LSWD]; Note from Italy, *Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)18, at 2 (2 June 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)18/en/pdf [https://perma.cc/66GU-ZUKV]; Competition and Mkt. Auth., *Pricing algorithms*: *Economic Working Paper on the Use of Algorithms to Facilitate Collusion and Personalised Pricing* 5 (CMA 94, 2018) (UK), https://assets.publishing.

Algorithmic tacit collusion - that is, the use of algorithms to execute unilateral and rational reactions to market characteristics that reflect interdependence - will not affect every (or even most) markets. As *Virtual Competition* explores,[27] one would expect to observe algorithmic tacit collusion in markets with several important characteristics:

First, algorithmic tacit collusion likely would arise in concentrated markets involving homogenous products where the algorithms can monitor, to a sufficient degree, the competitors' pricing, other keys terms of sale, and any deviations from the current equilibrium.[28] Software may be used to report and take independent action when faced with a rival's deviation, be it from the supra-competitive or recommended retail price. Conscious parallelism would be facilitated and stabilized to the extent (i) these the rivals' reactions are predictable, or (ii) through repeated interactions, the firms' pricing algorithms "could come to 'decode' each other, thus allowing each one to better anticipate the other's reaction."[29] As the OECD observed,

> The increase of market transparency is not only a result of more data being available, but also of the ability of algorithms to make predictions and to reduce strategic uncertainty. Indeed, complex algorithms with powerful data mining capacity are in a better place to distinguish between intentional deviations from collusion and natural reactions to changes in market conditions or even mistakes, which may prevent unnecessary retaliations.[30]

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service.gov.uk/government/uploads/system/uploads/attachment_data/file/746353/Algorithms_econ_report.pdf (noting that "algorithmic pricing may be more likely to facilitate collusion in markets which are already susceptible to coordination, . . . For these 'marginal' markets, the increasing use of data and algorithmic pricing may be the 'last piece of the puzzle' that could allow suppliers to move to a coordinated equilibrium. There could also be greater scope for coordination where algorithmic pricing takes place in an online context where price monitoring and response can happen particularly quickly."); SELECT COMMITTEE ON EUROPEAN UNION, *supra* note 7, ¶¶ 178-79; Note by the Russian Federation, *Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)22 (May 15, 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)22/en/pdf [https://perma.cc/4CM2-SSK3]; Report by Israel, *Annual Report on Competition Policy Developments in Israel,* OECD Doc. DAF-COMP-AR(2018)9 (May 2, 2018), https://one.oecd.org/document/DAF/COMP/AR(2018)9/en/pdf [https://perma.cc/KCB9-PM94]; Rod Sims, Chairman, Australian Competition and Consumer Comm'n [ACCC], *The ACCC's Approach to Colluding Robots*, Remarks at "Can robots collude?" Conference, ACCC (Nov. 16, 2017) (Austl.), https://www.accc.gov.au/speech/the-accc's-approach-to-colluding-robots [https://perma.cc/54GC-C3BZ].

[27] EZRACHI & STUCKE, *supra* note 6.

[28] Guidelines on the Assessment of Horizontal Mergers under the Council Regulation on the Control of Concentrations between Undertakings, 2004 O.J. (C 31) 5, ¶ 41 [hereinafter EC Merger Guidelines]; Note from Singapore*, Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)24, at 2 (May 31, 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)24/en/pdf [https://perma.cc/7HFV-AYTU].

[29] Note from the European Union, *supra* note 12, at 8.

[30] Background Note by the Secretariat, *supra* note 22, at 20.

A *second* important market condition is that once deviation (e.g., discounting) is detected, a credible deterrent mechanism exists.[31] Unique to an algorithmic environment is the speed of retaliation.[32] Computers can rapidly detect deviations, and calculate the profit implications of a myriad of moves and counter-moves to punish deviations.[33] The speed of calculated responses effectively deprives discounting rivals of any significant sales. The speed also means that the tacit collusion can be signalled in seconds. The greater the improbability that the first-mover will benefit from its discounting, the greater the likelihood of tacit collusion.[34] Thus, if each algorithm can swiftly match a rival's discount and eliminate its incentive to discount in the first place, the threat of future retaliation keeps the coordination sustainable.[35] Noteworthy are the European Commission's observations in its 2015-16 e-commerce sector inquiry,

> About half of the retailers track online prices of competitors. In addition to easily accessible online searches and price comparison tools, both retailers and manufacturers report about the use of specific price monitoring software, often referred to as 'spiders', created either by third party software specialists or by the companies themselves. This software crawls the internet and gathers large amounts of price related information. 67% of those retailers that track online prices use (also) automatic software programmes for that purpose. Larger companies have a tendency to track online prices of competing retailers more than smaller ones . . . some software allows companies to monitor several hundred online shops extremely rapidly, if not in real time . . . Alert

[31] EC Merger Guidelines, *supra* note 31; Note from the European Union, *supra* note 12, at 8 (noting that "tacit collusion requires effective retaliation, which in turn requires spare capacity" as a "capacity-constrained firm cannot initiate a price war as a means of retaliation to enforce tacit collusion").

[32] *But see* EC Merger Guidelines, *supra* note 31, ¶ 53 ("The speed with which deterrent mechanisms can be implemented is related to the issue of transparency. If firms are only able to observe their competitors' actions after a substantial delay, then retaliation will be similarly delayed and this may influence whether it is sufficient to deter deviation.").

[33] Jill Priluck, *When Bots Collude*, NEW YORKER (Apr. 25, 2015), http://www.newyorker.com/business/currency/when-bots-collude [https://perma.cc/35D6-CMB4].

[34] Samuel B. Hwang & Sungho Kim, Dynamic Pricing Algorithm for E-Commerce*, in* ADVANCES IN SYSTEMS, COMPUTING SCIENCES AND SOFTWARE ENGINEERING 149-155 (Khaled Elleithy & Tarek Sobh eds., 2006); Naoki Abe & Tomonari Kamba, *A Web Marketing System with Automatic Pricing*, 33 COMPUTER NETWORKS 775 (2000); Lusajo M. Minga et al., Dynamic Pricing: E-Commerce-Oriented Price Setting Algorithm*, in* PROCEEDINGS OF THE 2003 INTERNATIONAL CONFERENCE ON MACHINE LEARNING AND CYBERNETICS 893 (2003).

[35] Commission Decision of 20 December 2001 Declaring a Concentration to be Compatible with the Common Market and the EEA Agreement (Case COMP/M.2389 Shell/DEA), 2003 O.J. (L 15) 35, ¶ 121 ("The retaliation mechanism must be sufficiently plausible and effective to counterbalance the existing degree of probability and incentives to deviate in the market situation of the individual case . . . If the parties take the view that retaliation is costly, then the cost of deviating by winning a contract in deviation from a coordinated pattern in the first place is very high, too, and reduces the likelihood of such action.").

> functionalities in price monitoring software allow companies to get alerted as soon as a retailer's price is not in line with a predefined price.[36]

In such an environment, deviation would likely be unprofitable. The algorithm, in maximizing profits, "would need to decide that it is a better course of action than competitive pricing, especially if competitive pricing leads to drastically larger sales volumes."[37]

A *third* condition is that "the reactions of outsiders, such as current and future competitors not participating in the coordination, as well as customers, should not be able to jeopardise the results expected from the coordination."[38] Thus, algorithmic tacit collusion will likely arise in concentrated markets where buyers cannot exert buyer power (or entice sellers to defect), sales transactions tend to be "frequent, regular, and relatively small,"[39] and the market in general is characterized by high entry barriers.

To be clear, no bright line exists of when an industry becomes sufficiently concentrated for either express or tacit collusion.[40] Indeed, competition agencies often struggle in predicting when a merger may facilitate tacit collusion. In addition, it is important to stress that the above

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[36] *Commission Staff Working Document: Preliminary Report on the E-commerce Sector Inquiry* ¶¶ 550-551, SWD(2016) 312 final (Sept. 15, 2016); *Ecossistemas Digitais, Big Data e Algoritmos* [*Digital Ecosystems, Big Data and Algorithms*], AUTORIDADE DA CONCORRENCIA [PORTUGUESE COMPETITION AUTH.] (July 2019), http://www.concorrencia.pt/vPT/Noticias_Eventos/Comunicados/Documents/Issues%20Paper_%20Ecossistemas%20Digitais%20Big%20Data%20Algoritmos.pdf [https://perma.cc/J3VC-JELK] (Portuguese competition authority finding that 37% of surveyed companies used specific software to track competitor prices, and of those 79% adjusted their prices in reaction to the information obtained through the algorithm).

[37] Note by the European Union, *supra* note 12, at 8. As the OECD noted, "market stagnation characterised by declining demand and the existence of business cycles may hinder collusion. This is because firms have strong incentives to profitably deviate when demand is high and reducing the costs of retaliation in future periods when demand is low." Background Note by the Secretariat, *supra* note 22, at 20.

[38] EC Merger Guidelines, *supra* note 31, ¶ 41.

[39] U.S. Fed. Trade Comm'n & U.S. Dep't of Justice, *Commentary on the Horizontal Merger Guidelines,* U.S. DEP'T OF JUSTICE 19 (Mar. 2006), https://www.justice.gov/atr/file/801216/download [https://perma.cc/3ATK-FEEQ].

[40] Note, for example, research by Levenstein and Suslow, who offer several explanations for the lack of a clear empirical relationship between industry concentration and cartels involving express collusion:

> First, this ambiguity may reflect the bias introduced by focusing on cartels that were prosecuted by the U.S. Department of Justice; cartels with large numbers of firms or that had the active involvement of an industry association may have been more likely to get caught. Second, industries with a very small number of firms may be able to collude tacitly without resort to explicit collusion. Third, concentration is endogenous: collusion may have allowed more firms to survive and remain in the market.

Margaret C. Levenstein & Valerie Y. Suslow, *What Determines Cartel Success?*, 44 J. ECON. LITERATURE 43, 58 (2006).

phenomenon will affect a select number of markets. Still, when the above three conditions are present, the risk of tacit collusion is greater.

Importantly, the nature of electronic markets, the availability of data, and the adoption of similar algorithms by key providers will likely push some markets that were just outside the realm of tacit collusion into interdependence.[41] Furthermore, in such circumstances, tacit collusion is likelier to be sustained over time. The market stability needed for tacit collusion (that is, the absence of significant price deviations from the tacitly collusive price) is enhanced by the fact that computer algorithms are unlikely to exhibit human biases.[42] Human biases, of course, may be reflected in the programming code. But biases will not necessarily affect decisions on a case-by-case basis: a computer does not fear detection and possible financial penalties or incarceration; nor does it respond in anger.[43] Once programmed to execute a certain pricing policy, the computer will follow the plan. "We're talking about a velocity of decision-making that isn't really human," said Terrell McSweeny, a former Commissioner with the US Federal Trade Commission. "All of the economic models are based on human incentives and what we think humans rationally will do. It's entirely possible that not all of that learning is necessarily applicable in some of these markets."[44]

Looking at the market for pricing algorithms, one can see software vendors who are currently promoting their price optimization algorithms as a way to avoid price wars and increase prices and margins. Boomerang, for example, promotes how its price optimization software can "put an end to price wars before they even begin."[45] As the Italian competition authority

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[41] One would expect tacit collusion to be feasible with a larger number of participants than commonly assumed. On the common market assumptions, see generally Reinhard Selten, *A Simple Model of Imperfect Competition, Where Four Are Few and Six Are Many*, 2 INT'L J. GAME THEORY 141 (1973); Steffen Huck et al., *Two Are Few and Four Are Many: Number Effects in Experimental Oligopolies*', 53(4) J. ECON. BEHAV. & ORG. 435 (2004).

[42] EC Merger Guidelines, *supra* note 31, ¶ 44 (observing that "[c]oordination is more likely to emerge if competitors can easily arrive at a common perception as to how the coordination should work. Coordinating firms should have similar views regarding which actions would be considered to be in accordance with the aligned behaviour and which actions would not."); Note from Singapore, *supra* note 28, at 2.

[43] Maurice E. Stucke & Ariel Ezrachi, *How Pricing Bots Could Form Cartels and Make Things More Expensive*, HARV. BUS. REV. (Oct. 27, 2016), https://hbr.org/2016/10/how-pricing-bots-could-form-cartels-and-make-things-more-expensive [https://perma.cc/D946-EMMP].

[44] David Lynch, *Policing the Digital Cartels*, FIN. TIMES (Jan. 29, 2017), http://www.pros.com/about-pros/news/financial-times-policing-digital-cartels/ [https://perma.cc/M49X-F9SW].

[45] Abhijeet Sathe, *How Retailers and Brands Can Avoid the Race to the Bottom in Online Pricing*, INTERNET RETAILER (July 9, 2018), https://www.digitalcommerce360.com/2018/07/09/how-retailers-and-brands-can-avoid-the-race-to-the-bottom-in-online-pricing/ [https://perma.cc/3YDF-EZXY].

observed, "a number of specialized software developers offer solutions that allow even small companies to implement 'strategic' dynamic pricing strategies, offering tools to 'auto-detect pricing wars' as well as to 'help drive prices back up across all competition.'"[46]

Ultimately, we may see more instances in which similar pricing is not the result of fierce competition, nor the result of cartel activity, but rather the result of algorithmic tacit collusion. In those affected markets, one may witness the same result as express collusion, namely higher prices, with antitrust enforcers powerless to intervene.

II. THE (IN)STABILITY OF TACIT COLLUSION ABSENT COMMUNICATION

Algorithmic tacit collusion does not pervade the entire digital economy. It will likely only arise in markets with the characteristics discussed in Part I. Some critics, however, have questioned the likelihood of sustainable algorithmic tacit collusion even in these markets. As we explain below, their arguments, however, have failed to persuade enforcers and courts with respect to tacit collusion in the brick-and-mortar economy. Nor are they likely to gain traction in the digital economy.

In discounting the possibility of tacit collusion—whether by humans or algorithms—several economists point to earlier scholarship, which highlights the important role of communications in stabilizing and optimizing collusion.[47] They argue that while collusion without communication may be possible, it is highly unlikely. To their minds, the increase in transparency, speed in retaliation, and frequency in contacts are insufficient, even under the three market conditions outlined in Part I. According to this view, markets with more than two companies need some kind of explicit coordination (like communications) to enter into and sustain collusion. In extending the consensus that communication facilitates alignment (the exact level of communication needed remains unclear),[48] and that complex market realities would make collusion and tacit collusion difficult,[49] they argue that absent communication, tacit collusion is unlikely. Their argument is that "firms are unlikely to develop a mutual

[46] Note from Italy, *supra* note 26, at 3.

[47] *See* Kühn & Tadelis, *supra* note 16; Schwalbe, *supra* note 16.

[48] Kai-Uwe Kühn et al., *Fighting Collusion by Regulating Communication Between Firms*, 16 ECON. POL'Y 167 (2001); Yu Awaya & Vijay Krishnay, On Tacit Versus Explicit Collusion (November 3, 2014) (unpublished working paper, Pennsylvania State University), https://ssrn.com/abstract=2518707 [https://perma.cc/X647-778Y].

[49] For instance, where the environment is dynamic, demand is uncertain, and competition is not limited to price. *See* Edward Green et al., *Tacit Collusion in Oligopoly*, 2 OXFORD HANDBOOK INT'L ANTITRUST ECON. 464-97 (2014).

understanding over a collusive strategy absent direct communication in the initiation phase."[50]

According to this view, even in simple markets that exhibit the characteristics outlined in Part I, a coordination problem exists in markets with more than two rivals.[51] Accordingly, to increase the likelihood of stable tacit collusion, one would require some form of communication either to kickstart or sustain the collusion.[52]

The issue is principal and goes beyond the discussion of algorithmic collusion. This body of scholarship suggests that, many times, tacit coordination is unlikely absent some form of illicit communication or centralized orchestration, even in markets with three rivals.[53] These findings are often based on empirical observations under laboratory conditions with perfect control and transparency over communications. Permitting the human subjects to communicate, even briefly, increased their ability to enter into and sustain coordination, and higher prices with higher numbers of participants. Absent communications, collusion in these experiments was difficult, if not impossible, to reach and sustain.

If one accepts this claim, the unavoidable need for communication among firms would bring the parallel behavior into the realm of antitrust enforcement and enable agencies to condemn it as an anticompetitive agreement or concerted practice under well-established case law. Thus, if algorithms do not (or cannot) "communicate" with one another, then algorithmic tacit collusion is unlikely.[54] Thus, when we observe what appears to be tacit collusion in these markets, it is likely the result of illegal human communications.

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[50] David P. Byrne & Nicolas de Roos, *Learning to Coordinate: A Study in Retail Gasoline*, 109 AM. ECON. REV. 591 (2019) (noting, but not necessarily agreeing, with economic theories of collusion that "presume collusive agreements are initiated through explicit communication or remaining agnostic as to how such an understanding emerges").

[51] This is so, since the number of collusive equilibria present in a repeated game defies the simple alignment of prices. On the role of communications, see Joseph E. Harrington et al., *The Relative Efficacy of Price Announcements and Express Communication for Collusion: Experimental Findings*, 128 J. ECON. BEHAVIOR & ORG. 251 (2016); Miguel A. Fonseca & Hans-Theo Normann, *Explicit vs. Tacit Collusion–The Impact of Communication in Oligopoly Experiments*, 56 EUR. ECON. REV. 1759 (2011); David J. Cooper & Kai-Uwe Kühn, *Communication, Renegotiation, and the Scope for Collusion*, 6 AM. ECON. J.: MICROECONOMICS 247 (2016); Joseph Farrell & Matthew Rabin, *Cheap Talk*, 10 J. ECON. PERSPECTIVES 103 (1996); Vincent P. Crawford & Joel Sobel, *Strategic Information Transmission*, 50 ECONOMETRICA 1431 (1982).

[52] Independent of the discussion here, it has been shown that after a period of collusion supported by regular communication, firms are able to maintain collusive prices even when communication is no longer possible. *See* Fonseca & Normann, *supra* note 51.

[53] *See, e.g.*, Schwalbe, *supra* note 16.

[54] Indeed, the degree of coordination required to align the algorithms would increase the risk of exposure and civil (and potentially criminal) liability.

So why have these criticisms failed to persuade enforcers and courts with respect to tacit collusion in the brick-and-mortar economy, and why are they unlikely to gain traction in the digital economy?

When competition agencies or courts observe conscious parallelism that yields supra-competitive pricing, they do not assume that the competitors must be communicating with each other to jump-start or sustain the tacit collusion. As we illustrate below, the law in both the US and EU recognizes that, under certain market conditions, companies can behave as rational agents and adjust to market characteristics without *any* communications. The classic example is one gas station in a remote town silently reacting to the pricing of its competitors across the street.[55] As courts note, "One does not need an agreement to bring about this kind of follow-the-leader effect in a concentrated industry."[56] Such phenomenon, while dampening price competition, is legal and will not trigger intervention. As the US Supreme Court held:

> Tacit collusion, sometimes called oligopolistic price coordination or conscious parallelism, describes the process, not in itself unlawful, by which firms in a concentrated market might in effect share monopoly power, setting their prices at a profit-maximizing, supracompetitive level by recognizing their shared economic interests and their interdependence with respect to price and output decisions.[57]

Both EU and US antitrust law recognizes that anticompetitive "behavior can sometimes be coordinated without any communication or other observable and reprehensible behavior."[58] That is why "[t]acit coordination is feared by antitrust policy even more than express collusion, for tacit coordination, even when observed, cannot easily be controlled directly by the antitrust laws."[59] In recognizing this possibility, antitrust plaintiffs in the EU and US can only attack this tacit collusion indirectly.[60]

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[55] *In re* Nexium (Esomeprazole) Antitrust Litig., 42 F. Supp. 3d 231, 250 (D. Mass. 2014), *aff'd*, 842 F.3d 34 (1st Cir. 2016) (noting how "[g]as stations in a geographically isolated region, for example, are likely to engage in parallel supracompetitive pricing behavior because each gas station understands that matching the highest price in the region encourages prices to stay uniformly high without hurting demand, and that all local competitors are likely to independently reach the same conclusion.").

[56] *See id.* (quoting Clamp–All Corp. v. Cast Iron Soil Pipe Inst., 851 F.2d 478, 484 (1st Cir. 1988)).

[57] Brooke Group v. Brown & Williamson Tobacco Corp., 509 U.S. 209, 227 (1993) (citations omitted); *see also* F.T.C. v. H.J. Heinz Co., 246 F.3d 708, 725 (D.C. Cir. 2001).

[58] CITY OF COLUMBIA V. OMNI OUTDOOR ADVERT., INC., 499 U.S. 365, 396 N. 10 (1991) (QUOTING 6 PHILLIP E. AREEDA, ANTITRUST LAW ¶1400, AT 3-4 (REV. ED. 1986)).

[59] *Heinz*, 246 F.3d at 725 (quoting 4 PHILLIP E. AREEDA ET AL., ANTITRUST LAW ¶ 901b2, at 9 (rev. ed. 1998)).

[60] *Heinz*, 246 F.3d at 725; Max Huffman, *Marrying Neo-Chicago with Behavioral Antitrust*, 78 ANTITRUST L.J. 105, 134–35 (2012) ("Consciously parallel conduct does not provide a basis for Section 1 liability under the current state of the law, but the potential for conscious parallelism is relevant to

One way is for the US Federal Trade Commission to attack practices that facilitate tacit collusion under its broader powers under Section 5 of the FTC Act, which it hasn't actively pursued in the past few decades.[61] Another way is to target mergers that foster tacit collusion, precisely because this behavior, which can be accomplished without any communications or agreement among rivals, is otherwise difficult to prosecute.[62]

With the above in mind, we observe a gap between the law and the criticism according to which, communication is needed to enter into or stabilize conscious parallelism, and industry awareness will not suffice to support a common strategy. The law posits that anticompetitive parallel behavior among a few firms can naturally occur in markets with the conditions outlined in Part I. Indeed, it can occur with sufficient frequency in these markets that the law will not presume any underlying communications. For if the courts believed that communications often accompanied conscious parallelism, a legal presumption would likely arise.[63]

This notion affects both ex ante merger review and ex post antitrust enforcement. In the case of merger review, the realization that tacit collusion may emerge when the market conditions in Part I are present will justify careful scrutiny of proposed transactions that would foster conscious

merger review under Clayton Act Section 7, and there have been calls for FTC Act Section 5 enforcement against conscious parallelism.").

[61] Rudolph J.R. Peritz, *Toward A Dynamic Antitrust Analysis of Strategic Market Behavior*, 47 N.Y.L. SCH. L. REV. 101, 117 (2003); Spencer Weber Waller, *Prosecution by Regulation: The Changing Nature of Antitrust Enforcement*, 77 OR. L. REV. 1383, 1390 n. 31 (1998) ("The high (or low) point of FTC enforcement of Section 5 of the FTC Act challenging tacit collusion and oligopoly came in the late 1970s and early 1980s in three unsuccessful cases against the oil, fuel additives, and cereal industries. The oil investigation was eventually dropped after years of investigation. The FTC lost the other two matters. *See* E.I. Du Pont de Nemours & Co. v. FTC, 729 F.2d 128 (2d Cir. 1984); In re Kellogg Co., 99 F.T.C. 8 (1982).").

[62] *Heinz*, 246 F.3d at 725 (quoting 4 PHILLIP E. AREEDA, HERBERT HOVENKAMP & JOHN L. SOLOW, ANTITRUST LAW ¶ 901b2, at 9 (rev. ed. 1998)) ("It is a central object of merger policy to obstruct the creation or reinforcement by merger of such oligopolistic market structures in which tacit coordination can occur."); *FTC Commissioner McSweeny: FTC Must Use All Available Tools to Evaluate Mergers*, THOMSON REUTERS PRACTICAL LAW LEGAL UPDATE W-000-6233 (Sept. 30, 2015) ("Commissioner McSweeny explained that because antitrust enforcers can do little to remedy conscious parallelism and other forms of coordination in an already concentrated market, they should use the coordinated effects theory to predict and potentially prevent tacit collusion. Commissioner McSweeny noted that the guidelines allow agencies to challenge mergers without specific evidence of how potential coordination would manifest, and listed market factors that may link higher concentration with an increased risk of coordination, including: ease of entry or expansion; product homogeneity; market elasticity; customer switching costs; contract duration; transaction transparency.").

[63] Eastman Kodak Co. v. Image Tech. Servs., Inc., 504 U.S. 451, 466-67 (1992) ("Legal presumptions that rest on formalistic distinctions rather than actual market realities are generally disfavored in antitrust law.").

parallelism. In the case of ex-post antitrust enforcement, the realization that tacit collusion may emerge when market conditions are present may provide an explanation to the parallel conduct and bring it outside the scope of Section 1 of the Sherman Act and Article 101 of the EU's TFEU. Accordingly, even when private plaintiffs, the Department of Justice (DOJ), or European agencies have ample evidence of anticompetitive parallel behavior, that in itself, will not serve as proof of an agreement or illicit concerted practice, when the market conditions for tacit collusion are present.[64] Courts instead will assume that tacit collusion is likely and will require additional proof, which often include evidence of illicit communication.[65] It is only when parallel behavior cannot be explained as the outcome of tacit collusion (or due to other factors), that it may serve as proof of illegal collusion. As the European Court of Justice held:

> Although parallel behaviour may not by itself be identified with a concerted practice, it may however amount to strong evidence of such a practice if it leads to conditions of competition which do not correspond to the normal conditions of the market, having regard to the nature of the products, the size and number of the undertakings, and the volume of the said market.[66]

It is for the competition agency and private plaintiff to establish that no other explanation for the parallel behavior is present, which is difficult to prove in oligopolistic markets.[67] This is because the market may display the conditions for tacit collusion which can explain the parallel behavior. And so, the case law puts the onus on the antitrust plaintiff to prove the implausibility of rational unilateral reaction to market characteristics.[68] But

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[64] *See, e.g.*, Bell Atl. Corp. v. Twombly, 550 U.S. 544, 554 (2007) ("The inadequacy of showing parallel conduct or interdependence, without more, mirrors the ambiguity of the behavior: consistent with conspiracy, but just as much in line with a wide swath of rational and competitive business strategy unilaterally prompted by common perceptions of the market."); Harlem River Consumers Co-op., Inc. v. Associated Grocers of Harlem, Inc., 408 F. Supp. 1251, 1278 (S.D.N.Y. 1976) ("It is well established that consciously parallel business behavior does not of itself constitute a violation of the antitrust laws.").

[65] *See, e.g., In re* Chocolate Confectionary Antitrust Litig., 801 F.3d 383, 398 (3d Cir. 2015) ("[E]vidence of conscious parallelism cannot alone create a reasonable inference of a conspiracy," so in order to "move the ball across the goal line, a plaintiff must also show that certain plus factors are present," as these "plus factors are 'proxies for direct evidence' because they 'tend to ensure that courts punish concerted action—an actual agreement—instead of the unilateral, independent conduct of competitors.'" The court highlighted "traditional non-economic evidence of a conspiracy as the most important plus factor," which looks for "proof that the defendants got together and exchanged assurances of common action or otherwise adopted a common plan even though no meetings, conversations, or exchanged documents are shown.").

[66] Case 48/69, Imperial Chemical Industries Ltd. v. Comm'n, 1972 E.C.R. 619, 655.

[67] *See In re* Flat Glass Antitrust Litig., 385 F.3d 350, 360-61 (3d Cir. 2004).

[68] *See, e.g.,* Case T-442/08, CISAC v. Comm'n, ECLI:EU:T:2013:188, ¶182 (2013).

the "most important evidence will generally be non-economic evidence that there was an actual, manifest agreement not to compete."[69]

One example is *CISAC v. Commission* where the European General Court quashed a finding by the European Commission that parallel behavior between collecting societies was the result of illegal collusion with the aim of dividing the market.[70] The Court held that the Commission did not establish the requisite legal standard of the existence of collusion between the collecting societies to fix the national territorial limitations. The evidence relied upon by the Commission was not sufficient to render implausible the explanation that the national territorial limitations were the result of individual, carefully considered, and rational decisions, given the specific conditions of the market and not the result of a concerted practice.[71] The Court held that "the Commission must show precise and consistent evidence in order to establish the existence of the infringement."[72] Indeed, it is settled case law that "where the Commission's reasoning is based on the supposition that the facts established in its decision cannot be explained other than by concentration between the undertakings, it is sufficient for the applicants to prove circumstances which cast the facts established by the Commission in a different light and thus allow another explanation of the facts to be substituted for the one adopted by the Commission."[73]

Thus, the case law accepts that absent proof of express collusion or communication, parallel action and tacit collusion may be the only explanation of the market outcome.[74] Consumers may be harmed by the

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[69] *In re Flat Glass Antitrust Litig.*, 385 F.3d at 361 (citations omitted).

[70] Case T-442/08, CISAC v Comm'n, 5 C.M.L.R. 15 (2013).

[71] *Id.* ¶ 95.

[72] *Id.* ¶ 96.

[73] *Id.* ¶ 99.

[74] *See, e.g.*, Washington Cty. Health Care Auth., Inc. v. Baxter Int'l Inc., 328 F. Supp. 3d 824, 832 (N.D. Ill. 2018). The court stated:

> For several reasons, the probative force of plaintiffs' allegations of parallel conduct is particularly weak. Chief among them is that the IV saline market is an oligopoly in which "conscious parallelism"—"a common reaction of firms in a concentrated market that recognize their shared economic interests and their interdependence with respect to price and output decisions"—is to be expected. In other words, absent additional factual allegations, the mere fact that Baxter and Hospira restricted their own production of IV saline solution output after learning of output reductions by the other sheds little light on the existence *vel non* of an unlawful agreement. Yes, it is possible that Baxter and Hospira's behavior stemmed from a violation of the antitrust laws—*i.e.,* that it was the result of an agreement. But the nature of an oligopoly makes it such that there is a substantial likelihood that—even absent an agreement—Baxter and Hospira would have tried to capitalize on output restrictions signaled by the other, as it was in their independent interests to restrict supply and drive up prices. In short, parallel conduct in an oligopolistic market is not particularly probative of collusion.

higher prices, yet the law cannot condemn the parallelism as illegal.[75] In other words, the courts and agencies accept that tacit collusion is not only legal, but likely and sustainable in concentrated industries. Absent proof of an agreement, the plaintiff cannot challenge the anticompetitive conduct.

In an interesting case from 2015, the Court of Appeals for the Seventh Circuit explored price alignment without any actual communications among the parties. The opinion is noteworthy as its author, Judge Richard Posner, in his earlier writings, thought that it was "improbable that prices could long be maintained above cost in a market, even a highly oligopolistic one, without some explicit acts of communication and implementation."[76]

Nonetheless, writing for the Seventh Circuit, Judge Posner accepted the notion that anticompetitive tacit collusion can occur without any such communication:

> As for the apparent anomaly of competitors' raising prices in the face of falling costs, that is indeed evidence that they are not competing in the sense of trying to take sales from each other. However, this may be not because they've agreed not to compete but because all of them have determined independently that they may be better off with a higher price. That higher price, moreover—the consequence of parallel but independent decisions to raise prices—may generate even greater profits (compared to competitive pricing) if costs are falling, provided that consumers do not have attractive alternatives.[77]

In this case, the action taken by the companies was deemed unilateral and reflected an economic rationale, in light of each firm's demand function.[78] The Seventh Circuit recognized that anti-competitive pricing could arise from purely tacit collusion: "There isn't even evidence that [an

Id. (citations omitted). *See also* Case 48/69, Imperial Chemical Industries Ltd. v. Comm'n, 1972 E.C.R. 619, ¶ 8 ("Although parallel behaviour may not by itself be identified with a concerted practice, it may however amount to strong evidence of such a practice if it leads to conditions of competition which do not correspond to the normal conditions of the market, having regard to the nature of the products, the size and number of the undertakings, and the volume of the said market.").

[75] *See, e.g., In re* Flat Glass Antitrust Litig., 385 F.3d 350,360 (3d Cir. 2004) (noting how the Supreme Court has described conscious parallelism in dicta as "the process, *not in itself unlawful*, by which firms in a concentrated market might in effect share monopoly power, setting their prices at a profit-maximizing, supracompetitive level by recognizing their shared economic interests and their interdependence with respect to price and output decisions.").

[76] Richard A. Posner, *Oligopoly and the Antitrust Laws: A Suggested Approach*, 21 STAN. L. REV. 1562, 1574 (1969).

[77] *In re* Text Messaging Antitrust Litig., 782 F.3d 867, 871-72 (7th Cir. 2015).

[78] *Id*. at 876.

employee of the defendant] had ever communicated on any subject with any employee of any of the other defendants."[79] As the court noted,

> [T]he Sherman Act imposes no duty on firms to compete vigorously, or for that matter at all, in price. This troubles some antitrust experts, such as Harvard Law School Professor Louis Kaplow, whose book Competition Policy and Price Fixing (2013) argues that tacit collusion should be deemed a violation of the Sherman Act. That of course is not the law, and probably shouldn't be. A seller must decide on a price; and if tacit collusion is forbidden, how does a seller in a market in which conditions (such as few sellers, many buyers, and a homogeneous product, which may preclude nonprice competition) favor convergence by the sellers on a joint profit-maximizing price without their actually agreeing to charge that price, decide what price to charge?[80]

The courts assume that "[c]ompetitors in concentrated markets watch each other like hawks."[81] Each competitor will copy or respond to competitive responses without necessarily communicating with one another. And "it is not a violation of antitrust law for a firm to raise its price, counting on its competitors to do likewise (but without any communication with them on the subject) and fearing the consequences if they do not."[82]

How does one reconcile the views of the courts and enforcers on the one hand and the discrete subset of economists on the other hand?

One explanation is that the case law is simply wrong. Tacit collusion is unlikely and communications are occurring, but the colluders are effectively covering their tracks. We are presented with a case of a Type II error (false negative) where courts are dismissing cases when they should be finding liability.

For example, in the *Text Messaging Antitrust Litigation,* the parties were embroiled in three years of discovery, culminating in the district judge's grant of the defendants' motion for summary judgment.[83] The heart of the plaintiffs' case were two emails between two T-Mobile executives. In the first e-mail, the executive writes, "Gotta tell you but my gut says raising messaging pricing again is nothing more than a price gouge on consumers. I would guess that consumer advocates groups are going to come after us at some point. It's not like we've had an increase in the cost to carry message to justify this or a drop in our subscription SOC rates? I

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[79] *Id*. at 873.
[80] *Id*. at 873-74.
[81] *Id*. at 875.
[82] *Id.* at 876.
[83] *Id.* at 869.

know the other guys are doing it but that doesn't mean we have to follow."[84] The second e-mail -- sent in the wake of a congressional investigation of alleged price gouging by the defendants – noted said that "at the end of the day we know there is no higher cost associated with messaging. The move [the latest price increase by T–Mobile] was colusive [*sic*] and opportunistic."[85] Judge Posner summarily disposed of this "smoking gun" evidence:

> the plaintiffs' counsel demonstrate a failure to understand the fundamental distinction between express and tacit collusion. Express collusion violates antitrust law; tacit collusion does not. There is nothing to suggest that [the T-Mobile executive] was referring to (or accusing his company of) express collusion. In fact the first email rather clearly refers to tacit collusion[.][86]

While some economists doubt the ability to enter and sustain conscious parallelism,[87] the law assumes that it is possible without illicit communication and does not intervene.

The problem is that if one were to reject the prevailing legal viewpoint, we may quickly shift to a Type I error (false positive), where courts reach a positive result (finding the defendants liable for price-fixing) when they should reach a negative one (finding the defendants not liable because they never agreed with one another). All the plaintiff would have to show in markets with more than two competitors is an anticompetitive outcome – whether by tacit or express collusion. If anticompetitive conscious parallelism/tacit collusion is considered implausible without communication, the court would infer communications among the competitors. Once the court makes this inference, it is a small step to infer from the unobserved communications -- along with the observed anticompetitive behavior – an agreement among the rivals, and thus liability under EU and US law. Under such approach, the distinction between express and tacit collusion would fade as the agencies, antitrust plaintiffs, and courts would assume an illegal agreement whenever observing conscious parallelism with anticompetitive outcomes.[88] This, of

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[84] *Id.* at 872.

[85] *Id.*

[86] *Id.*

[87] *See* Schwalbe, *supra* note 16; Schrepel, *supra* note 16; Kühn & Tadelis, *supra* note 16; *Transcript of FTC Hearings Session No. 7: Competition and Consumer Protection in the 21st Century - Day 1*, *supra* note 16; *Transcript of FTC Hearings Session No. 7: Competition and Consumer Protection in the 21st Century - Day 2, supra* note 9.

[88] One potential rebuttal is that the antitrust plaintiffs should still have to hunt for evidence of the communications. But why? When there is fire, why would the court require plaintiffs to prove independently the existence of smoke? If what you are observing—namely the anticompetitive coordination—is only possible with communications, then why would the courts require the plaintiff to

course, would send shivers down the defense bar's and their clients' spines. Courts would presume that firms communicated, even when they have not. And how would they prove that they did not communicate? To avoid prosecution, firms will be required to operate irrationally in the market.

A second explanation focuses on the misalignment between market realities and the experimental evidence upon which some economists rely. According to this explanation, economic experiments, carried in laboratories with test subjects that interact over a period of a few hours (and with absolute control over communications), do not necessarily provide a good proxy for actual market behavior where awareness of interdependence exists absent illicit communications. The lab experiments do not reflect the interdependence of tacit collusion (and often discount the stability of actual collusion). In practice, firms can sustain tacit collusion without illicit communication as they operate with awareness that develops over time, as to the market dynamics, and the benefit they may attain from parallelism and the avoidance of price wars. Firms that operate over long periods of time in these highly concentrated markets benefit from "industry awareness" and understand the interdependence among their actions.[89] That awareness emerges from a large number of abstract signals and observations, none of which triggers antitrust intervention, and can reduce uncertainty about future actions with long-lasting effects on coordination. This awareness may substitute communication in a laboratory setting and, at the very least, provide a plausible explanation to the durable conscious parallelism.

Whichever explanation one favors, either way – when determining illegality – the law rejects the argument that communication is essential to establish tacit collusion. Quite the contrary, the law accepts that when market conditions for tacit collusion are present, conscious parallelism yielding anticompetitive outcomes may be sustained. Put simply, tacit coordination can exist "without any actual communication among competitors."[90]

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expend time and resources to prove the communication? In the end, tacit collusion would always violate Section 1 of the Sherman Act and Article 101 of TFEU.

[89] *See, e.g.*, Rumina Dhalla & Christine Oliver, *Industry Identity in an Oligopolistic Market and Firms' Responses to Institutional Pressures,* 34 ORG. STUD. 1803 (2013); Margaret Peteraf & Mark Shanley, *Getting to Know You: A Theory of Strategic Group Identity*, 18 STRATEGIC MGMT. J. 165 (1997).

[90] U.S. Fed. Trade Comm'n, Comment on Proposed Confidentiality Determinations for Data Required Under the Mandatory Greenhouse Gas Reporting Rule and Proposed Amendment to Special Rules Governing Certain Information Obtained Under the Clean Air Act (September 30, 2010), 2010 WL 9440202, at *6 n.3; *In re* High Fructose Corn Syrup Antitrust Litigation, 295 F.3d. 651, 654 (7th Cir. 2002) (noting that a tacit agreement to fix prices is "an agreement made without any actual communication among the parties to the agreement").

Returning to our discussion of algorithms, the same legal approach applies. When we raised our scenarios of algorithmic tacit collusion, most enforcers, judges, and lawyers recognized this possibility. It derived naturally from the law and market reality that they encountered over the decades. Moreover, other economists and game theorists accept tacit collusion without communications.[91] But, if one assumes that the skeptics are right, then the gap between their beliefs and the law has widened. If the skeptics are right, humans have somehow successfully skirted antitrust liability for decades by convincing enforcers that parallel behavior can naturally occur under some market conditions and is not the result of illicit communications. But because pricing algorithms cannot engage in this "stealth communication," algorithmic tacit collusion should be impossible. If true, then whenever enforcers observe what appears to be conscious parallelism in markets dominated by pricing algorithms, they have a stronger case to argue that the humans must have communicated. For any other explanation is impossible. But the enforcers and courts, to date, have not adopted this presumption. They recognize the possibility that humans may engage in illicit communication to limit competition (in which case they will prosecute them for cartel activity), but also recognize humans and algorithms may react unilaterally to market dynamics and tacitly collude without explicit (and illicit) communications.

Another anomaly emerges. If the critics are correct, in industries conducive to tacit collusion, firms would have little, if any, incentive to use pricing algorithms. These firms apparently have a golden ticket – they can charge supra-competitive prices through stealth human communications without the threat of antitrust liability. So, one would not expect industries characterized by such tacit collusion – like gas stations – to switch to pricing algorithms. For if they did, their prices and profits, without the stealth human communications, would likely drop. If the prices don't drop, then one must assume, under this economic theory, that the firms, as in the *Topkins* case in the US[92] and the *Trod* and *GBE* cases in the UK,[93] not only

[91] *See* Marc Ivaldi et al., *The Economics of Tacit Collusion - Final Report for Directorate General for Competition, European Commission* (Mar. 2003), https://ec.europa.eu/competition/mergers/studies_reports/the_economics_of_tacit_collusion_en.pdf [https://perma.cc/C3CS-JYKL]; *see generally* 6 PHILLIP E. AREEDA & HERBERT HOVENKAMP, ANTITRUST LAW (3d ed. 2010); FREDERIC SCHERER & DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE (3d ed.1990).

[92] Plea Agreement at 1, United States v. Topkins, No. CR 15-00201 (N.D. Cal. 2015) (pleading guilty to agreeing with his co-conspirators to fix the prices of certain posters sold in the United States through Amazon Marketplace, where the conspirators used specific pricing algorithms to implement their illegal oral agreement).

[93] The UK antitrust authority found in 2016 that Trod Ltd. and GB eye Ltd. infringed the competition law by agreeing that they would not, in certain specified circumstances, undercut each other's prices for posters and frames sold on Amazon's UK website, and used pricing algorithms to

agreed to collude, but also communicated with each regarding the algorithms needed to implement and sustain their collusion. Thus, the level of communications between competitors should significantly increase as firms switch to pricing algorithms.

Thus, courts and competition authorities have largely marginalized the "tacit collusion is impossible without communications" arguments. Indeed, as we discuss below, the emerging evidence justifies the courts' and agencies' skepticism of the skeptics.

III. THE (IM)PLAUSIBILITY OF ALGORITHMIC TACIT COLLUSION

Let us now move to a second, related issue which merits our attention – whether pricing algorithms can support anticompetitive conscious parallelism. If we accept the legal premise that conscious parallelism can occur without the communications that expose firms to antitrust liability, then the issue is whether algorithms can facilitate tacit collusion, and do so, in a superior manner to that of humans.

Some contend that even if tacit collusion without communication were possible in the brick-and-mortar economy when rivals watch each other like hawks, and react to each other's pricing and competitive moves, that does not mean it is possible in industries where prices are set by algorithms (and perhaps for some firms by humans). The potentially large number of pricing options presented by algorithms creates complexity, which will likely decrease the likelihood of alignment in a repeated game – that is, algorithms will unlikely obtain and sustain tacit collusion. In what follows, we consider this argument.

Let us start by stating the obvious. This discussion does not concern "the rise of the machines" nor the creation of "evil" algorithms that seek to profit at the expense of consumers. It is a somewhat less exciting debate about the possibility that human-designed algorithms might offer a superior instrument for the optimization of pricing decisions, in markets that may support conscious parallelism. In that respect, one should note the limits of the pricing algorithm. It will not necessarily change the basic characteristics of every market, nor will it overcome instability that results from lower barriers to entry, maverick companies, or fierce competition. The tool at hand, at times, will amplify the power to monitor and punish in instances when humans see a benefit in sustaining parallel behavior.

When discussing the extension of human will, it is helpful to distinguish between "simple" adaptive algorithms that are programmed to

facilitate their illegal agreement. *See* U.K. Competition & Mkts. Auth., *CMA Issues Final Decision in Online Cartel Case*, GOV.UK (Aug. 12, 2016), https://www.gov.uk/government/news/cma-issues-final-decision-in-online-cartel-case [https://perma.cc/U9GU-73MG].

monitor and "react," and more sophisticated self-learning algorithms that rely on artificial intelligence to autonomously determine the optimal strategy. That simplified distinction is of value for our discussion, as it helps identify instances in which the executives appreciated how their use of pricing algorithms would very likely foster conscious parallelism (thus, we have evidence of anticompetitive intent, but not necessarily communications), and instances in which humans do not intend to facilitate conscious parallelism through their use of algorithms. Let us explore both categories.

A. Simple Algorithms

Humans can program adaptive algorithms to reflect a pricing strategy that assumes interdependence on the market or is geared to push toward such interdependence. Humans observe the market dynamics and identify the desirability of parallelism. They subsequently program the algorithm to reflect the unilateral actions of a rational agent in this tight oligopoly. Detection and punishment of deviation are imbedded into the algorithmic pricing decision-making, in addition to the upward price adjustment that follows the price leader.

In essence, tacit collusion happens at the human level and leads humans to utilize technology in order to stabilize it. As we saw in Part II, the law in the US and EU accepts that when market conditions are apt, such conscious parallelism can be established unilaterally, as humans develop an awareness of market dynamics and appreciate the interdependence among the rivals. As a result, the enforcers (other than the FTC) and private plaintiffs cannot legally challenge the new equilibrium (absent evidence of express collusion). The FTC can attempt to reach the industry-wide use algorithms as a facilitating practice.

However, how likely is algorithmic tacit collusion without communications? To test the dynamic described above, let us start in the lab. Professors Nan Zhou, Li Zhang, Shijian Li, and Zhijian Wang devised a Linear Extortion to Collusion Algorithm (LECA) which can "enforce its human rival to collude."[94] Professors Nan Zhou and his colleagues then designed an algorithm-human game, where a human competed against the LECA algorithm for 600 rounds.[95] In each round, the human and algorithm could decide the quantity of a product to produce. Importantly, for our purposes, they could not otherwise communicate with each other, nor did

[94] Nan Zhou et al., Algorithmic Collusion in Cournot Duopoly Market: Evidence from Experimental Economics (Feb. 21, 2018) (unpublished working paper, Zhejiang University), https://arxiv.org/pdf/1802.08061.pdf [https://perma.cc/7DHQ-MDBP].

[95] *Id*.

the human know of the algorithm's pricing strategy. After they each select a quantity of products they wanted to produce, they were told the human subject's and algorithm's profits. Over the first 300 iterations of the competition game, the humans learned that reducing quantity to reach the almost fully collusive level would secure the greatest profits. After learning this, the humans kept their quantity at the collusive level thereafter. In their Algorithm-Human duopoly market, the degree of tacit collusion rose to nearly 100% in rounds 300 to 400. What is interesting is that the time to establish tacit collusion (about 400 rounds) in the algorithm-human experiment was far quicker than in the human-human collusion (about 800 rounds) experiments. Using an algorithm that is programed to achieve conscious parallelism resulted in a superior result than leaving that task to humans. From their experiments, the study's authors concluded that *first,* algorithms can facilitate tacit collusion more quickly, and *second*, there exists incentives for firms to use such algorithms in the market.

That experiment, as the authors recognized, involved a duopoly. Now let us consider tacit collusion in markets with multiple competitors.

Suppose an oligopolistic gas station market with limited transparency, such that prices are only visible when reaching each gas station. In this market, customers can mitigate the search costs by asking friends about any available deals, visit a few gas stations, and support the station with the lowest price. Here a gas station, by discounting, may increase its profits and develop a reputation for having a low (if not, the lowest) price. At times, competitors, aware of the price reductions and promotions would respond with their own initiative. Even when the gas prices are more transparent, there is a lag for rivals to discover the lower price, because of monitoring time and costs. Their delayed response is likely to benefit the station with the reputation as a discounter. Under these market conditions, conscious parallelism is harder to sustain. The firms will likely compete as expected. We see here how markets "need to be sufficiently transparent to allow the coordinating firms to monitor to a sufficient degree whether other firms are deviating, and thus, know when to retaliate."[96] This would especially be the case where customers are aware of the price, while competitors do not (for example, when there are significant and frequent discounts).

When transparency and the rivals' speed in responding to competitive behavior increase in concentrated markets with homogeneous goods, so too does the risk of tacit collusion. With computerized pricing, the process may be faster and more stable. To foster parallelism, companies may adopt a

[96] EC Merger Guidelines, *supra* note 31, ¶ 49.

pricing strategy that would be easy to decipher by competitors. Let us briefly illustrate with two examples.

First, in 2012, petrol stations in Chile were required to post their fuel prices on a government website and to keep prices updated as they changed at the pump. An economic study found that this Chilean regulation did not increase competition.[97] On the contrary, the petrol stations' margins increased by 10%, on average, following the prices being posted on the government website.[98]

Second, in Germany, the government suspected that an oligopoly of five firms -- BP (Aral), ConocoPhillips (Jet), ExxonMobil (Esso), Shell, and Total – dominated the off-motorway petrol station business.[99] To promote competition, the government required the petrol stations to report to its government's transparency unit any price changes for gasoline or diesel fuel in "real-time."[100] The government's transparency unit then transmitted the price data to consumers, with the aim that they could easily find the cheapest petrol nearby. One economic study found that rather than lowering prices, the enhanced market transparency actually increased prices further. Compared to the control group, retail petrol prices increased by about 1.2 to 3.3 euro cents, and diesel increased by about 2 euro cents.[101]

Other studies also suggest an increase in transparency can facilitate tacit collusion.[102]

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[97] Fernando Luco, *Who Benefits from Information Disclosure? The Case of Retail Gasoline*, 11 AM. ECON. J.: MICROECONOMICS 277 (2019).

[98] *Id*. The softening of competition was common across brands and was not limited to a single Chilean city. Interestingly, although the stations' margins increased across Chile, the effect was not uniform: the petrol station margins "increased the most in areas with low or non-existent consumer search (low-income areas), while they increased the least, and even decreased, in areas with high search intensity (high-income areas)."

[99] *Fuel Sector Inquiry Final Report*, BUNDESKARTELLAMT (May 2011), http://www.bundeskartellamt.de/SharedDocs/Publikation/EN/Sector%20Inquiries/Fuel%20Sector%20Inquiry%20-%20Final%20Report.pdf?__blob=publicationFile&v=14 [https://perma.cc/VE74-V289] (Together, the five companies had a combined share of approx. 64.6% of the annual fuel sales, with the remainder distributed among "a few other large oil companies and a large number of small and medium sized oil traders.").

[100] Ralf Dewenter et al., *The Impact of the Market Transparency Unit for Fuels on Gasoline Prices in Germany* (Düsseldorf Institute for Competition Economics Discussion Paper No. 220, 2016), http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche_Fakultaet/DICE/Discussion_Paper/220_Dewenter_Heimeshoff_Lueth.pdf [https://perma.cc/37Z2-RBLG].

[101] *Id*. at 5. More generally, we also note another interesting study on the impact of price matching guarantee as stabilizing tacit collusive mechanism in petrol markets. *See* Luís Cabral et al., *Learning Collusion: Theory and Evidence from a Gasoline Market Price Matching Guarantee*, CRESSE 1 (March 2018), http://www.cresse.info/uploadfiles/2018_ps11_pa2.pdf [https://perma.cc/TKF8-XMEN].

[102] *See, e.g.*, David P. Byrne & Nicolas de Roos, *Learning to Coordinate: A Study in Retail Gasoline*, 109 AM. ECON. REV. 592 (2017) (finding the systematic use of prices rather than explicit communication as a tool for tacit coordination); Tabled Paper by Griffith University Submitted to the

First, these outcomes, which make sense under the legal standard, are harder to explain under the "no collusion absent communications" theory. Under this economic theory, the government's increase in transparency should not have prompted the rivals to increase prices further. Because sustaining tacit collusion among five competitors is implausible, in view of this economic theory, the oligopolists must have been actively communicating to sustain their supra-competitive pricing. They conceivably would have communicated their dissatisfaction with each other after their daily drive.

Rather, the result is consistent with the legal acknowledgment of sustained tacit collusion where each competitor watches the others like hawks. To monitor pricing, the gas station owners in Germany would drive past specified competitor gas stations several times a day and note their prices. The monitored prices were then fed into the respective gasoline company's electronic system. Generally, when one competitor increased its gas prices, rivals generally would respond between three to six hours later.[103] Now, with increased transparency from the online pricing, the rivals can monitor and punish promptly.

So, the increase in fuel prices was not the likely result of "communications." Instead, it likely reflects tacit collusion, where firms who are aware of their interdependence, recognize that they will profit by acceding to the higher price rather than discounting.

With pricing algorithms, the retaliation time is further reduced. As each firm taps into its rivals' real-time pricing, no gas station likely profits

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Legislative Assembly of Queensland, *The Impact of MyFuelNT on retail ULP prices in the Northern Territory*, QUEENSL. PARLIAMENT (May 2018), http://www.parliament.qld.gov.au/Documents/TableOffice/TabledPapers/2018/5618T565.pdf__[https://perma.cc/VUZ7-5YMC] (finding "that the MyFueINT scheme had a small but significant positive impact" on retail ULP prices in Australia's Northern Territory. Significant anticompetitive price effects were found across Darwin, Alice Springs and Katherine. As the authors note, the results of the study "should be treated with caution due to 1) limitations of the data, 2) changes in the sampling methodology 3) omitted variable bias.").

[103] Dewenter et al., *supra* note 100:

> If a round of price increases is begun by Aral, Shell reacts in 90% of the cases exactly three hours later with a price increase in all of the regional markets, thereby adjusting its price level to that of Aral. Vice-versa, when Shell starts a round of price increases, in 90% of the cases Aral follows suit, again after exactly three hours. Total also generally reacts with price rises in all of the regional markets three or three-and-a-half hours after the start of the price round. Jet and Esso also react in the same way to rounds of price increases started by Aral or Shell, although the response patterns differ in some of the regional markets. Nevertheless, it can be concluded that Jet often also raises its prices five hours after the start of a round of price increases, whereby it generally observes a price difference of one eurocent/litre to Aral and Shell's prices. Esso reacts between three and six hours after the start of a round of price increases. It is also apparent that on some regional markets Jet and Esso only react to rounds of price increases started in the evenings on the morning of the following day.

by discounting. Given the velocity with which the pricing algorithms can adjust, each gas station will less likely develop among its customers a reputation as a price discounter. Accordingly, the competitors will have less incentive to discount.

On the flip side, the algorithms' velocity of pricing decisions can shorten the time period for signaling price increases in other industries. Firms would no longer have to rely on lengthy (e.g., thirty-day) advanced price announcements, where they wait and see what the competitive response is to decide whether to actually raise prices and to what extent. Computers can have multiple rounds whereby one firm increases prices and the rivals respond immediately and without the risk that the firm that initiates the price increase will lose many customers to rivals. Essentially, companies may now need only seconds, rather than days, to signal price increases to foster tacit collusion.

As we shift from a world where rivals drive around town to see the price that their rivals charge to a world in which pricing algorithms can achieve this same price monitoring mechanism within milliseconds, the human logic to maximize profits remains. Importantly, the algorithms help effectuate this logic. Needless to say, algorithms will not immunize market participants from disruptive technologies, entrants, or mavericks. However, absent such threats, the market participants can use pricing algorithms to sustain tacit collusion (and do so without entering into any illicit communication or concerted practice).

In an attempt to further stabilize the conscious parallelism, humans may use additional means. They could, for example, limit variations in the design of the algorithms, making it easier to follow. Such unilateral moves, even when undertaken by several firms, are unlikely to trigger antitrust liability under current laws, absent proof of illicit communication or lack of rational (and legal) strategy behind the move. Further, companies may invest in better tools to observe and imitate pricing decisions executed by other algorithms. Companies may, for example, introduce price matching guarantees to further support monitoring as deterrent mechanisms.[104] The unilateral nature of the actions may well leave them outside the realm of Article 101 of TFEU, Section 1 of the Sherman Act, and even, Section 5 of the FTC Act.[105] Going a step further, humans may use algorithms in a more

[104] Price match may create an incentive to follow price increases by the price leader. *See* Cabral et al., *supra* note 101, at 2.

[105] *See, e.g.*, E.I. du Pont de Nemours & Co. v. F.T.C., 729 F.2d 128, 139-40 (2d Cir. 1984) (stating that to challenge the facilitating device, like a price matching guarantee, the FTC had to show (1) evidence that defendants tacitly or expressly agreed to the facilitating device to avoid competition, or (2) oppressiveness, such as (a) evidence of defendants' anticompetitive intent or purpose or (b) the absence of an independent, legitimate business reason for defendants' conduct).

aggressive way to decode the strategy used by competing algorithms and adjust accordingly.[106] Depending on the technology used, this might trigger intervention. But if each company unilaterally decides to use an algorithm to help decode its rivals' strategy, then the courts may find it perfectly legal (if plaintiff cannot prove an agreement or that the companies' actions qualify as a "facilitating practice").[107]

To avoid the need to invest in decoding competing algorithms, companies may adopt a different approach and use the same provider for their pricing algorithm, or alternatively, the same provider for their dynamic pricing strategies. This move would create a hub-and-spoke interaction, like the one discussed in the introduction.[108] Let us elaborate on this, using our example of gas stations.

Competing gas stations could use the same company for pricing decision-making. When multiple players use the same algorithm, data points, and values, the likelihood for alignment increases. According to the *Wall Street Journal*, one example is the market for petrol in Rotterdam, Netherlands, where a number of petrol stations used the same provider—the Danish company a2i Systems—for advanced analytics to determine petrol prices.[109] Importantly, note that the provision by the same company of dynamic pricing services, and the creation of a possible hub-and-spoke relationship, do not clearly infringe the competition laws. On its website, the company a2i Systems provides a case study to illustrate how it helped OK Benzin, Denmark's leading petrol station owner, avoid a price war:

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[106] *See* Michal S. Gal, *Algorithms as Illegal Agreements*, 34 BERKELEY TECH. L.J. 67, 67 (2019) (noting that "the algorithms is a 'recipe for action,' which can be directly or indirectly observed by competitors"); *see also* Bruno Salcedo, Pricing Algorithms and Tacit Collusion (Nov. 1, 2015) (unpublished manuscript), http://brunosalcedo.com/docs/collusion.pdf [https://perma.cc/8K7L-2JXP].

[107] Note from the European Union*, supra* note 12, at 8:

> [O]ne could argue that through repeated interactions, two firms' pricing algorithms could come to 'decode' each other, thus allowing each one to better anticipate the other's reactions. However, the case-law is clear that Article 101 'does not deprive economic operators of the right to adapt themselves intelligently to the existing and *anticipated conduct* of their competitors' . . . Short of signalling . . . it is therefore not obvious that more sophisticated tools through which a firm merely observes another firm's price and draws its own conclusion would qualify as 'communication' for Article 101 purposes.

[108] On liability for hub-and-spoke conspiracy, see Case C-74/14, Eturas v. Competition Council of the Republic of Lithuania, 4 C.M.L.R. 19 (2016); Interstate Circuit, Inc. v. United States, 306 U.S. 208, 227 (1939); Summary of Commission Decision of 4 February 2015 Relating to a Proceeding under Article 101 of the Treaty on the Functioning of the European Union and Article 53 of the EEA Agreement (Case AT.39861 — Yen Interest Rate Derivatives), 2017 O.J. (C 305) 10; Tesco v. Office of Fair Trading [2012] CAT 31 (UK).

[109] Sam Schechner, *Why Do Gas Station Prices Constantly Change? Blame the Algorithm,* WALL ST. J. (May 8, 2017), https://www.wsj.com/articles/why-do-gas-station-prices-constantly-change-blame-the-algorithm-1494262674 [https://perma.cc/UR8H-KX8E].

"Between 2007 and 2012 the market was characterized by fierce competition and high volatility. At the peak there were 10 to 20 price changes a day, and the spread between the highest and the lowest price of the day could be up to 15 eurocent."[110] In enlisting a2i Systems, the leading retail network of approximately 700 petrol stations (which accounted for 25% of the Danish retail fuel market), sought "to improve the pricing analysis and decision process and optimize pricing according to their overall strategy in order to lower the cost of price wars or better yet, to avoid them."[111] As the *Wall Street Journal* reported, the complex algorithm operated by a2i Systems was tested against a control group which did not use the system to determine price. The result? "The group using the software averaged 5% higher margins."[112] For the petrol company, a2i Systems notes, this "means millions of Euros" more, annually.[113]

Note that the a2i pricing algorithm was used to lower the cost of price wars or eliminate them altogether. This is not a case of a2i marketing its ability to coordinate a price-fixing cartel. That would subject it and the European petrol stations to civil liability. Rather, it is about the unilateral use of a decision-making algorithm to soften competition. It is about using the a2i pricing algorithm to service multiple clients.

The sharing of the same focal point, in our opinion, should raise concerns in such instances and call for some form of intervention. The Hub-and-Spoke algorithmic structure brings us further away from typical tacit collusion, but is yet to be challenged by competition agencies. It is important to stress that it differs from a cartel being facilitated by a hub-and-spoke structure.[114] (The head of the DOJ in 2018 intimated a potential criminal case that may inform the legality of this practice.[115]) Indeed, it is

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[110] *PriceCast Fuel Case Story*, A2I SYSTEMS (Nov. 2011), https://www.a2isystems.com/wp-content/uploads/2018/11/PriceCast-Fuel-Case-Story-15.pdf [https://perma.cc/2HAB-SRRU].

[111] *Id.*

[112] Schechner, *supra* note 109.

[113] *Id.*

[114] Interstate Circuit, Inc. v. United States, 306 U.S. 208 (1939) (finding an antitrust price-fixing conspiracy based on a hub-and-spoke conspiracy theory, where one actor (the "hub"), such as a distributor, enters into agreements with a number of actors (the "spokes"), such as movie studios, who are aware that the distributor is entering into similar agreements with each movie studio and that the success of the plan agreed to depends on the studios all performing in accordance with the agreements).

[115] The head of the DOJ Antitrust Division said that the anticompetitive use could take a couple of forms, either two potential competitors using the same algorithm "as a way of effectuating a price-fixing scheme. . . . We actually have a case that's a criminal case that is going to be coming to conclusion in the next two weeks, I think, and then we will make public the use of that, and I believe it is the first of its kind." John Eggerton, *Delrahim: Criminal Case Against Anti-competitive Search Algorithms Coming*, BROADCASTINGCABLE (Oct. 4, 2018), https://www.broadcastingcable.com/news/delrahim-criminal-case-against-anti-competitive-search-algorithms-coming [https://perma.cc/R4B2-MH62].

an "incidental" hub-and-spoke, which while not driven by a cartel agreement, may nonetheless facilitate alignment. The UK Competition and Markets Authority expressed the greatest concern over this algorithmic hub-and-spoke structure, "because it simply requires firms to adopt the same algorithmic pricing model."[116] As we indicated in *Virtual Competition*, such incidental hub-and-spoke, while not indicative of a cartel agreement, could nonetheless undermine competition.

Let us move beyond hub-and-spoke and note how algorithms may be used to amplify the effects of anticompetitive agreements.

One recent example involves resale price maintenance (RPM), which is where the manufacturer/distributor agrees with the retailer on what the minimum price should be for the manufacturer's product. Absent RPM, some retailers may discount that product to attract customers and increase sales. Historically, the manufacturer would monitor and individually punish retailers that sold the manufacturer's product below its suggested retail price. For example, after punishing retailer A, the manufacturer would shift its attention to retailers B, C, and D. Punishing each offending retailer increases the manufacturer's potential risks of antitrust liability, especially in jurisdictions where RPM is per se (or presumptively) illegal.[117]

But in an environment in which pricing algorithms are used, the manufacturer may achieve the same outcome without communicating with each of the offending retailers. In its e-commerce sector inquiry, the European Commission found that retailers were increasingly using automatic software "for price monitoring and price setting."[118] Many, including the biggest online retailers, are using "pricing algorithms which automatically adapt retail prices to those of competitors."[119] In this environment, the manufacturer need not punish every offending retailer. Instead, the manufacturer would only have to punish one or two significant retailers that are discounting, and whose prices the other retailers' pricing algorithms are tracking and matching. Once these discounters raise their

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[116] Competition and Mkt. Auth., *supra* note 26.

[117] RPM is presumptively illegal in Europe and in some states in the US. *See* A.B.A Pricing Conduct, Corporate

Counseling, and International Committees, *Around the World Enforcement Update on Resale Price Maintenance* 30-37 (July 11, 2016), https://www.americanbar.org/content/dam/aba/publications/antitrust_law/20160711_at160711_materials.authcheckdam.pdf [https://perma.cc/PDJ4-XH2S]; Michael A. Lindsay, *Repatching the Quilt: An Update on State RPM Laws*, 13 ANTITRUST SOURCE (Feb. 2014). RPM was per se illegal for nearly a century under the Sherman Act until the Supreme Court, in a controversial 5-4 decision, subjected it to a more deferential rule of reason standard. *See* Leegin Creative Leather Prod., Inc. v. PSKS, Inc., 551 U.S. 877 (2007).

[118] European Commission Press Release IP/18/4601, Antitrust: Commission Fines Four Consumer Electronics Manufacturers for Fixing Online Resale Prices (July 24, 2018).

[119] *Id*.

prices, the other retailers' pricing algorithms will automatically follow. The manufacturer's risk of detection and ensuing antitrust liability is reduced, due to the more limited communications.[120]

The Commission observed this anticompetitive dynamic in a 2018 vertical price-fixing case. As the Commission found, because many, including the biggest online retailers, were using pricing algorithms that automatically adapted the retail prices to those of competitors, the resale "pricing restrictions imposed on low pricing online retailers typically had a broader impact on overall online prices for the respective consumer electronics products."[121] In effect, the consumer electronics manufacturer only had to punish a few online discounters, and could be assured that many other retailers would automatically increase their prices. Thus, even in industries not susceptible to tacit collusion, one can obtain the same effect when manufacturers vertically fix prices with one significant retailer, and the other retailers' pricing algorithms automatically follow suit. Consequently, the emerging evidence suggests that enforcers will likely uncover evidence of anticompetitive human intent in using relatively "simple" algorithms to sustain tacit collusion without any evidence of actual communications. After all, tech firms currently promote how their price optimization software can put an end to price wars before they even begin.

B. Artificial Intelligence

Now, let us turn to our fourth scenario, *Digital Eye*, where we raise the question of whether conscious parallelism could be established by self-learning algorithms without the humans' express intent or direction. Could algorithms that are based on reinforced learning provide a superior tool to sustain tacit collusion? And if so, when left to their own devices, might the pricing algorithms identify conscious parallelism as a superior strategy?

The question is whether in future markets, where the majority of pricing decisions will involve minimal human intervention, price levels may be established above competitive levels – not as a result of express collusion, nor as a result of humans appreciating the benefits of tacit collusion (and programming their pricing algorithms accordingly), but rather the result of action taken by independent learning algorithms that take account of various data points.

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[120] Background note by the Secretariat*, Hub and Spoke Arrangements,* OECD Doc. DAF/COMP(2019)14 (Oct. 17, 2019), https://one.oecd.org/document/DAF/COMP(2019)14/en/pdf [https://perma.cc/R5KW-EMP6].

[121] *See* European Commission Press Release IP/18/4601, *supra* note 118.

We are beginning to see Wall Street firms shift from simpler, programmed algorithms to machine-learning algorithms that pick the optimal trading strategy. As *The Economist* observed in 2019:

> Quant funds can be divided into two groups: those like Stockfish [the best chess game engine programmed with human tactics], which use machines to mimic human strategies; and those like AlphaZero [Google's self-learning computer program that had been given only the rules of chess and then taught itself how to play], which create strategies themselves. For 30 years quantitative investing started with a hypothesis, says a quant investor. Investors would test it against historical data and make a judgment as to whether it would continue to be useful. Now the order has been reversed. "We start with the data and look for a hypothesis," he says.
>
> Humans are not out of the picture entirely. Their role is to pick and choose which data to feed into the machine. "You have to tell the algorithm what data to look at," says the same investor. "If you apply a machine-learning algorithm to too large a dataset often it tends to revert to a very simple strategy, like momentum."
>
> But just as AlphaZero found strategies that looked distinctly inhuman, Mr Jacobs of Lazard says AI-driven algorithmic investing often identifies factors that humans have not. The human minders may seek to understand what the machine has spotted to find new "explainable" factors. Such new factors will eventually join the current ones. But for a time they will give an advantage to those who hold them.[122]

Again, we should start by stressing that the issue is not about algorithms conspiring against humans, but rather, whether a self-learning algorithm that is programmed to optimize profit by interacting in a dynamic environment, may identify conscious parallelism as an optimal strategy and identify unique means to foster this tacit collusion.

Much is still uncertain as to the capacity of future reinforced-learning or deep learning algorithms to reach conscious parallelism with no human intervention.[123] Doubts as to learning algorithms' ability to sustain collusion

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[122] *The Stock Market Is Now Run by Computers, Algorithms and Passive Managers*, ECONOMIST (Oct. 5, 2019), https://www.economist.com/briefing/2019/10/05/the-stockmarket-is-now-run-by-computers-algorithms-and-passive-managers [https://perma.cc/5PXT-HQRB].

[123] As the ACCC summarized:

> "Machine learning" and related "deep learning" technology enable software to autonomously improve its knowledge and processes through iteration and experience, without being explicitly programmed with new information or instructions. This can include:
>
> algorithms that teach machines to learn cause and effect by analyzing samples of data that were manually labelled in order to highlight clear distinctions between different features of data (supervised learning)

refer to their increased sophistication, which could make alignment difficult. Doubts are also linked to the need and ability of algorithms to establish a hidden channel of communication, that may address problems of entering and sustaining collusion.[124] While acknowledging current uncertainty, competition agencies around the world have begun looking into these developments. The technology is still at its infancy, but it is important to acknowledge that the tech industry is taking its first steps in this direction for its algorithms.

From an enforcement perspective, and at a high level of simplification, one may envisage two outcomes:

1. Outcome 1

If the algorithms are uncapable of autonomously reaching tacit collusion, humans in markets that tilt toward conscious parallelism would either train them to achieve that outcome, program them with human strategies that foster tacit collusion, or refrain from using the algorithms (as such use, absent any significant offsetting gains and efficiencies, would reduce profits). Accordingly, in a market where humans appreciate the benefits of interdependence, and can do so without infringing the competition laws, they would not introduce uncontrolled disruptors that could unleash a price war. They will continue using simple adaptive algorithms.

Indeed, we have not found that in the online context that any third-party developer of pricing algorithms that promotes its algorithms' ability to unleash and prevail in an all-out price war. If self-learning pricing algorithms reduced overall profits by destabilizing pre-existing tacit collusion, competitors would unlikely employ them. Thus, in industries already susceptible to tacit collusion, companies would ensure alignment of the learning algorithm with the overall strategy. They would ensure to exploit the freedom offered to them under the law and unilaterally use adaptive or simple algorithms. Under this scenario we return to our previous category of human-driven tacit collusion enhanced by algorithms.

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algorithms that try to identify hidden structures and patterns from unlabeled data (unsupervised learning)

algorithms performing tasks and learning through trial and error (reinforced learning).

ACCC, *Digital Platform Inquiry Final Report*, ACCC 523 (July 26, 2019), https://www.accc.gov.au/publications/digital-platforms-inquiry-final-report [https://perma.cc/NQA3-C6WU].

[124] For papers dismissing the possibility for algorithm-driven tacit collusion, *see* Schwalbe, *supra* note 16.

The question is whether such use should be condemned by competition law or remain unchallenged.

2. Outcome 2

If, on the other hand, self-learning algorithms could solve the coordination problem through trial- and-error and with no human intervention, then we face an additional complexity in the form of undetected and unchallenged conscious parallelism. In such scenarios, algorithms can learn through experimentation and without the knowledge of the human executives to shift from competitive pricing rules to collusive pricing rules and sustain that new anticompetitive equilibrium.

Economists and computer scientists are now exploring this avenue. Research has already shown how, under certain conditions, reinforcement learning can sustain cooperation.[125] Furthermore, learning algorithms have been shown to gravitate toward conscious parallelism in simple oligopolistic setting.[126] These observations support the possibility that self-learning algorithms may autonomously establish conscious parallelism with no human input in environments in which they operate in parallel (rather than only in simplified environments, in which they face a stable fixed-strategy opponent).

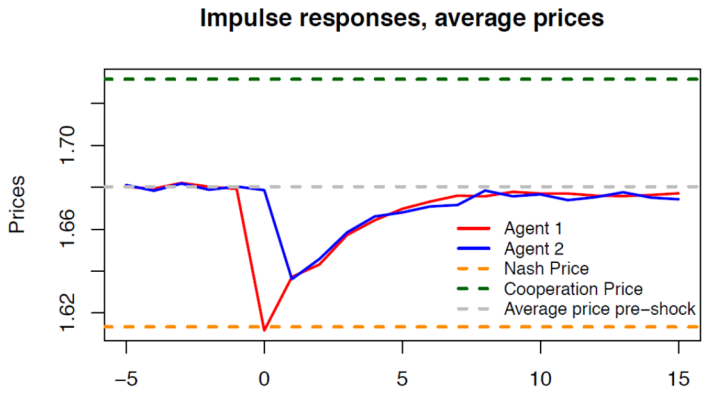
With all the uncertainty and caveats in mind, let us briefly note recent observations of one group of scholars who have shown that self-learning algorithms can have the capacity to achieve coordination on the tacit collusive outcome.[127] In experiments with two Q-learning pricing algorithms, tacit collusion emerged in more than 60% of the cases, and at even higher levels following sufficient simulation. Importantly, these results were observed in significantly rich environment with up to 100 price levels. As illustrated below, forcing a price deviation by one algorithm to the "Nash Price" (in this experiment, reflecting the static equilibrium price which would emerge if there was no tacit coordination), led the other Q-learning algorithm to react. Subsequently, both returned to the pre-existing

[125] *See*, *e.g.*, Jacob W. Crandall et al., *Cooperating with Machines*, 9 NATURE COMM. 233, 233, 240 (2018); Joel Z. 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, 469-71 (2017), http://www.ifaamas.org/Proceedings/aamas2017/pdfs/p464.pdf [https://perma.cc/8HXZ-ZSUQ] (analyzing fruit gathering and wolfpack hunting games, and illustrating conflict emergence and dilemmas affecting cooperation).

[126] *See* Timo Klein, *Autonomous Algorithmic Collusion: Q-Learning Under Sequential Pricing*, (Tinbergen Institute, Discussion Paper TI 2018-056/VII), https://papers.tinbergen.nl/18056.pdf [https://perma.cc/CB9K-KDPG]; Gerald Tesauro & Jeffrey O. Kephart, *Pricing in Agent Economies Using Multi-Agent Q-Learning*, 5 AUTONOMOUS AGENTS & MULTI-AGENT SYS. 289, 301-02 (2002).

[127] Emilio Calvano et al., *Algorithmic Pricing: What Implications for Competition Policy*?, 1 REV. INDUS. ORG. 155 (2019).

price level, which represents the tacit collusive equilibrium (which is above the competitive price, but below the monopolistic (cooperation) price). And so, the self-learning algorithms identified tacit collusion as an optimal strategy. When one of the pricing algorithms diverted from that price, the other algorithm reacted (thus making the diversion unprofitable), leading both to return to a higher anticompetitive price point, which, if applied in the real world, would benefit the companies, and harm the consumer. Importantly, this outcome was achieved without human guidance or programming.



Source: Calvano et al., *Q-Learning to Cooperate*[128]

In an extension of their experiment, Professors Calvano, Calzolari, Denicolò and Pastorello used three Q-learning algorithms (that is, more than what some argue is possible for tacit collusion without communications) in a rich price environment. Their experiment again found conscious parallelism and increased profitability with short learning times. The scholars observed how difficult it may be to detect such algorithmic tacit collusion: "What is most worrying is that the algorithms leave no trace of concerted action – they learn to collude purely by trial and error, with no prior knowledge of the environment in which they operate, without communicating with one another, and without being specifically designed or instructed to collude."[129]

[128] Emilio Calvano et al., *Q-Learning to Cooperate*, Address at the NBER Economics of Artificial Intelligence Conference 2018 (Sept. 14, 2018), slides *available at* https://conference.nber.org/conf_papers/f114616.slides.pdf [https://perma.cc/4YDF-VA3C].

[129] Emilio Calvano et al., *Artificial Intelligence, Algorithmic Pricing, and Collusion*, VOXEU.ORG (Feb. 3, 2019), https://voxeu.org/article/artificial-intelligence-algorithmic-pricing-and-collusion [https://perma.cc/6WTL-DAMS].

Researchers are continuing to experiment the likelihood of algorithmic tacit collusion in even more complex environments - with increased and changing numbers of algorithms, increased sophistication of algorithms, and increased price levels.

As the economist Ai Deng noted, the algorithm in the researchers' experiments took "an average of 850,000 periods of training to learn to 'tacitly collude.'"[130] While that amounts to less than one minute of CPU time, he noted that in the real world, the algorithms "learn" after 97 years if they change prices every hour, and companies may not allow the algorithm to learn on the job. So, companies will likely first train their algorithms off-line, which means they might know of their algorithms' capacity to collude and may take steps to enhance it.

We are still early in the development of AI and its application to pricing decisions. Uncertainty remains as to the operation of future markets, costs associated with the learning phase, the ability to simulate and operate in a multi-agent environment, and the likely competitive effects in different markets as the complexity and diversity of self-learning algorithms increase.[131] Furthermore, developments in the ability of algorithms to signal,[132] monitor, decode and communicate in stealth mode,[133] will affect any future equilibria. But we encourage researchers to continue to develop algorithmic tacit collusion incubators that model rich and realistic environments.

IV. RECOMMENDATIONS

If the current pricing algorithms leave no trace of their concerted action in the lab, then these self-learning algorithms – when unleashed in concentrated industries – may escape detection from the unwitting antitrust enforcer who assumes that this collusion will somehow be detected.

Pricing algorithm suppliers already tout, as a benefit, their clients' avoiding price wars. If this is real, and not marketing hype, then there are significant potential profits from algorithms that can foster tacit collusion.

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[130] Ai Deng, How Concerned Should We Be About Algorithmic Tacit Collusion? Comments on Calvano et al. (unpublished working paper, NERA Economic Consulting and Johns Hopkins University) (October 11, 2019), https://ssrn.com/abstract=3467923 [https://perma.cc/Z7KW-5YGQ].

[131] *See*, *e.g.*, Mary McGlohon & Sandip Sen, Learning to Cooperate in Multi-agent Systems by Combining Q-learning and Evolutionary Strategy (unpublished working paper, The University of Tulsa), http://www.cs.cmu.edu/~mmcgloho/pubs/wclc.pdf [https://perma.cc/R9J9-ME37].

[132] *See*, *e.g.*, Jacob W. Crandall et al., *Cooperating with Machines*, 9 NATURE COMMC'NS 233 (2018); *see also* Gal, *supra* note 106.

[133] *See*, *e.g.*, Martín Abadi & David G. Andersen, Learning to Protect Communications with Adversarial Neural Cryptography (Oct. 24, 2016) (unpublished working paper, Google Brain), https://arxiv.org/pdf/1610.06918.pdf [https://perma.cc/2HDP-XEJB].

This would represent an area ripe for further exploration by companies and developers of pricing algorithms, who, at present, benefit from an emerging gap in antitrust enforcement that may enable the attainment of higher profits (without the fear of antitrust liability, which includes in the US, criminal fines, incarceration, and treble damages for the injured antitrust plaintiffs).

This emerging gap merits closer consideration by competition agencies. But algorithmic tacit collusion can be even harder to detect – especially when the algorithms leave no trace of concerted action. As EU Commissioner Vestager noted, "[t]he trouble is, it's not easy to know exactly how those algorithms work. How they've decided what to show us, and what to hide. And yet the decisions they make affect us all."[134] Likewise, the UK competition authority recognized the "complexity of algorithms and the consequent challenge of understanding their exact operation and effects can . . . make it more difficult for consumers and enforcement agencies to detect algorithmic abuses and gather relevant evidence."[135] Even if the competition agencies detect tacit collusion, the current law limits their ability to challenge it.

So, where does this leave us?

If one accepts tacit coordination as a material risk in susceptible industries, then the competition agencies must develop tools to assess (and deter) this risk.[136] No doubt enforcement action, at times, will be challenging. After all, condemning rational reaction for market characteristics would, in itself, distort competition. Condemning it when it is assisted by bots may lead to a similar anomaly. Identifying, auditing, or monitoring algorithms may be expensive and illusive. Using means to affect market transparency, undermine detection, or delay reaction can undermine the essence of competition.

These challenges should give us a pause. When considering any likely enforcement action, we must acknowledge the costs of over-intervention. Yet, the cost of under-intervention must also be acknowledged, especially when premised on the theory that tacit collusion is implausible without

[134] Margrethe Vestager, Commissioner, European Commission, *Algorithms and Competition*, Remarks at Bundeskartellamt 18th Conference on Competition in Berlin (March 16, 2017), https://ec.europa.eu/commission/commissioners/2014-2019/vestager/announcements/bundeskartellamt-18th-conference-competition-berlin-16-march-2017_en [https://perma.cc/LD5J-HGE5].

[135] Note from the United Kingdom, *Algorithms and Collusion*, OECD Doc. DAF/COMP/WD(2017)19, at 12 (May 30, 2017), https://one.oecd.org/document/DAF/COMP/WD(2017)19/en/pdf [https://perma.cc/P7QA-NJSV].

[136] *See* Note by the European Union, *supra* note 12, at 9; Note by the United States, *supra* note 12, at 6; Note from the United Kingdom, *supra* note 135.

human communication. Consumers and enforcers with the current tools cannot blunt the siren song of profits from algorithmic tacit collusion.

So, what are three things that the United States and other jurisdictions can do to better understand and deter algorithmic tacit collusion?

The first step is to better understand the risks of algorithmic collusion. The French and German antitrust agencies conducted a joint research project to investigate algorithms and their implications on competition.[137] The European Commission has also announced a consultation process with a view towards shaping competition policy in the era of digitization. Thus, the US, where the FTC and DOJ are both currently investigating the tech platforms, should coordinate efforts with these other agencies.

Moreover, Germany's Monopolies Commission in 2018, offered several additional proposals to better understand the risks of algorithmic tacit collusion.[138] The Commission recommends, among other things, that the competition authorities systematically investigate markets with algorithm-based pricing for adverse effects on competition. Sector inquiries (which the FTC can undertake in the US), should be used more often to identify markets at risk. Additionally, consumer associations could be given a right to initiate competition sector inquiries, as they are most likely to receive information about potentially coordinated prices.

Competition agencies should also have dedicated teams dealing with algorithmic collusion and other competition issues raised by Big Data and AI. The Australian Competition & Consumer Commission, for example, has a Data Analytics Unit to analyze and build its expertise on pricing algorithms, help conduct market studies, and support the work of the antitrust agency's investigations teams and economists.[139]

After better understanding the risks of algorithmic collusion, the agencies' next step is to improve their tools in detecting collusion. Collusion -- whether express or tacit -- is already difficult to detect. In a market dominated by algorithms, the dynamic algorithmic price may be the only ascertainable price. Absent a natural experiment or counterfactual (such as a similar market without algorithms), enforcers may not readily discern whether (and why) the market price is too high. Is it the result of artificial intervention or natural supply and demand dynamics? One key tool that we discuss elsewhere is developing Algorithmic Collusion

[137] Autorité de la Concurrence & Bundeskartellamt*, supra* note 26. The results of the study were presented in Paris in November 2019.

[138] *Biennial Report of the Monopolies Commission under § 44(1) ARC*, MONOPOLKOMMISSION (July 3, 2018), https://www.monopolkommission.de/index.php/en/beitraege/223-concentration-among-companies [https://perma.cc/K455-5KZU].

[139] Sims, *supra* note 26.

Incubators, a computer simulation which takes into account the market characteristics, demand, and supply, and enables competition officials to test under what conditions tacit collusion occurs, and the effects and likelihood of different counter-measures to destabilize this conscious parallelism.[140] Basically, antitrust enforcers should use pricing algorithms deployed in the field to see pricing levels (and margins) for particular products. It would be of interest if the agency could inquire how algorithms responded in their simulations when one competitor exited (or entered) the marketplace (perhaps informing future merger review).

Third, once the agencies have a better understanding of the risks of algorithmic tacit collusion, and if the evidence shows that the use of pricing algorithms enhances collusive market results and obfuscates its discovery, then the agencies should consider updating current antitrust policies. Germany's Monopolies Commission, for example, considers two legal aspects:

- Reversal of the burden of proof in competition proceedings with regard to the damage caused by an infringement of competition law; meaning that the finding of a collusive use of price algorithms would give rise to the presumption of an excessive price.
- Far-reaching extension of liability for competition law infringements to third parties such as IT service providers regarding the design of price algorithms.

A primary way to deter tacit collusion is merger review. In markets where pricing algorithms are present and the risk of algorithmic tacit collusion is great, then the competition agencies should consider lowering their threshold of intervention and investigate the risk of coordinated effects not only in cases of 3 – to – 2 mergers, but also potentially also in 4 – to – 3 or even in 5 – to – 4 mergers, and to reconsider the approach to conglomerate mergers when tacit collusion can be facilitated by multimarket contacts.[141]

This may also require the agencies to distinguish their approach to human and algorithmic tacit collusion. It will likely require a refined approach that identifies and punishes instances where algorithms are used to facilitate collusion. A refinement of the approach to signalling may be a good place to start. Restrictions on certain market manipulations (through bots that underscore parallelism) may be another. The issue should be approached in a measured manner, and as part of the continual adjustment

[140] Ezrachi & Stucke, *supra* note 8, at 28.

[141] Background Note by the Secretariat, *supra* note 22, at 40.

of antitrust policy to market and technological reality. Failing to do so, may well lead us to future markets where a competitive price is a mere illusion, and *price optimization* is used as code for tacit collusion's supra-competitive profits.

CONCLUSION

Price-fixing cartels, despite the fines, leniency programs, and in some jurisdictions, criminal penalties, persist. Enforcers and policy makers increasingly recognize that their current antitrust enforcement tools are even more limited in effectively deterring algorithmic tacit collusion.[142] The current tools to combat price-fixing do not materially deter tacit collusion. And merger review, the primary mechanism to deter conscious parallelism, is likely misaligned with the true ability of markets to support algorithmic tacit collusion. As a result, competition will likely soften, and consumers will pay the price.

As brick-and-mortar shops are closing at a faster rate, as sellers and buyers migrate to the online world, and as technology, communications, big data and big analytics reach new highs, the effects of pricing algorithms will become more prominent. In the digitalised environment, tacit collusion might turn from being a mere outcome of market characteristics, into a strategy. While the phenomenon of tacit collusion is limited to markets with given characteristics, it nonetheless is likely to exhibit greater durability in an algorithm-driven environment.

So, with that risk in mind, we are encouraged that many policy makers and competition agencies are not only taking this risk seriously but are devoting resources to better understand the implications of algorithmic collusion. While it might not be as glamorous as the dawn raid, their efforts might deter competitors in devising pricing algorithms that can better exploit consumers.

[142] John Naughton, *How do you Throw the Book at an Algorithm?*, GUARDIAN (Dec. 4, 2016), https://www.theguardian.com/commentisfree/2016/dec/04/how-do-you-throw-book-at-an-algorithm-internet-big-data [https://perma.cc/FP7H-HPBM].