

# Sustainable and Unchallenged Algorithmic Tacit Collusion

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Algorithmic collusion has the potential to transform future markets, leading to higher prices and harm to consumer welfare. 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, 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 isn’t only possible, but warrants the increasing concerns of many enforcers.

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## 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.”<sup>1</sup> During the summer of 2018, the law firm noted,

*both 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...the 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.*<sup>2</sup>

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We are grateful for comments received from participants in the 2017 OECD roundtable on "Algorithms and Collusion" and the 2018 Max Planck Round Table Discussion on Tacit Collusion.

<sup>1</sup> Hogan Lovells, Digital competition policy on the move: Price algorithms in the German Monopolies Commission's spotlight (July 11, 2018).

<sup>2</sup> Id.

The European Commission is seeking input on these issues, as well.<sup>3</sup> The German Monopolies Commission, in its 2018 report, recommended the government “to systematically investigate markets with algorithm-based pricing for adverse effects on competition.”<sup>4</sup> Among the key concerns raised are pricing algorithms can help competitors elude detection for their price-fixing or with or without help of humans tacitly collude. With tacit collusion (conscious parallelism), there isn’t 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.<sup>5</sup> In 2016 we provided further context and analysis in our book, *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy*.<sup>6</sup> We developed our themes further in submissions to the U.K. House of Lords<sup>7</sup> and OECD.<sup>8</sup>

Broadly we have gleaned general consensus over our first two scenarios: *Messenger* where algorithms help humans collude, and *Hub and Spoke* where a common intermediary, which provides the algorithm and the pricing decision mechanism, could facilitate price-fixing.<sup>9</sup> Indeed, the European Commission and United States antitrust authorities, among others, raised concerns

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<sup>3</sup> <http://ec.europa.eu/competition/scp19/>.

<sup>4</sup> [https://www.monopolkommission.de/images/HG22/PM\\_HG\\_2018\\_EN.pdf](https://www.monopolkommission.de/images/HG22/PM_HG_2018_EN.pdf).

<sup>5</sup> Ezrachi and Stucke, ‘Artificial Intelligence & Collusion: When Computers Inhibit Competition’, Oxford Legal Studies Research Paper No. 18/2015, University of Tennessee Legal Studies Research Paper No. 267, available at SSRN: <https://ssrn.com/abstract=2591874> or <http://dx.doi.org/10.2139/ssrn.2591874>.

<sup>6</sup> *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy* (2016, HUP).

<sup>7</sup> Online Platforms and the EU Digital Single Market, prepared for the UK House of Lords, Internal Market Sub-Committee (16 October 2015).

<sup>8</sup> [https://one.oecd.org/document/DAF/COMP/WD\(2017\)25/en/pdf](https://one.oecd.org/document/DAF/COMP/WD(2017)25/en/pdf).

<sup>9</sup> See, e.g., Opinion of Advocate General Szpunar delivered on 11 May 2017 in Case C 434/15, *Asociación Profesional Elite Taxi v Uber Systems Spain SL*, at 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”); *Meyer v. Kalanick*, 174 F. Supp. 3d 817, 822–27 (S.D.N.Y.) (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).

that algorithms could facilitate collusion,<sup>10</sup> and have opened investigations on these scenarios.<sup>11</sup> Most policymakers recognize how “pricing algorithms may make price fixing attempts more frequent and potentially more difficult to detect.”<sup>12</sup> 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.”<sup>13</sup>

What has sparked debate, however, are our third and fourth scenarios, namely *Tacit Collusion on Steroids -- The Predictable Agent and Artificial Intelligence, God View, and the Digital Eye*. In our third scenario, we noted how already today, companies could unilaterally use algorithms with the intent to facilitate conscious parallelism (also known as tacit collusion). In the fourth scenario, we predicted that, in the future, algorithms may arrive at this anticompetitive outcome on their own. Our *Predictable Agent* and *Digital Eye* categories raise significant policy issues, including:

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<sup>10</sup> Algorithms and Collusion - Note by the European Commission, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)12, at 7 (14 June 2017); Algorithms and Collusion - Note by the United States, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)41, at 6 (26 May 2017) (“if 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.” Algorithms and Collusion - Note by the United States, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)41, at 6 (26 May 2017). 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.

<sup>11</sup> 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/> (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, *Software and stealth: how carmakers hike spare parts prices*, REUTERS (June 4, 2018), <https://www.reuters.com/article/autos-software-pricing/rpt-insight-software-and-stealth-how-carmakers-hike-spare-parts-prices-idUSL5N1T60H9>. No formal findings, however, have been found against the carmakers or Accenture.

<sup>12</sup> Terrell McSweeney, Commissioner, U.S. Federal Trade Commission, ‘Algorithms and Coordinated Effects’, University of Oxford Center for Competition Law and Policy (May 22, 2017), available at [https://www.ftc.gov/system/files/documents/public\\_statements/1220673/mcsweeney\\_-\\_oxford\\_cclp\\_remarks\\_-\\_algorithms\\_and\\_coordinated\\_effects\\_5-22-17.pdf](https://www.ftc.gov/system/files/documents/public_statements/1220673/mcsweeney_-_oxford_cclp_remarks_-_algorithms_and_coordinated_effects_5-22-17.pdf).

<sup>13</sup> Terrell McSweeney, Commissioner, U.S. Federal Trade Commission, ‘Algorithms and Coordinated Effects’, University of Oxford Center for Competition Law and Policy (May 22, 2017), available at [https://www.ftc.gov/system/files/documents/public\\_statements/1220673/mcsweeney\\_-\\_oxford\\_cclp\\_remarks\\_-\\_algorithms\\_and\\_coordinated\\_effects\\_5-22-17.pdf](https://www.ftc.gov/system/files/documents/public_statements/1220673/mcsweeney_-_oxford_cclp_remarks_-_algorithms_and_coordinated_effects_5-22-17.pdf).

- Does our current policy towards conscious parallelism apply when price optimization algorithms enhance firms' ability to tacitly collude?
- Is the legal concept of agreement outdated for computer algorithms? Are our current laws sufficient to deter and prevent tacit algorithmic 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 use of price optimization algorithms?
- In what way in which 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 there is little controversy that tacit collusion is generally beyond the reach of the competition laws of many jurisdictions, including the United States and European Union, some, however, have questioned the likelihood of tacit collusion in either the brick-and-mortar economy or digital economy. They argue that tacit algorithmic collusion should not pose any concern because collusion is unsustainable without communications.<sup>14</sup> The issue is whether companies, in concentrated industries ripe for tacit collusion, would have the incentive and ability to develop pricing algorithms for that purpose. Some economists have argued that tacit collusion with three or more rivals - whether by algorithms or humans - is unlikely, as the “coordination problems are hard to solve without communication, even in simple static game.”<sup>15</sup> According to this view, since algorithms cannot communicate to resolve this coordination problem, they cannot tacitly collude. And because pricing algorithms cannot tacitly collude, the antitrust laws – developed in the old economy – suffice for the digital economy.

In this paper, we explore their criticism and examine why it hasn't slowed the enforcers' interest

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<sup>14</sup> Ulrich Schwalbe 'Algorithms, Machine Learning, and Collusion'; Thibault Schrepel, Here's why algorithms are NOT (really) a thing, *Concurrentialiste*, May 2017, online: <https://leconcurrentialiste.com/2017/05/15/algorithms-based-practices-antitrust/>; Kai-uwe Kühn and Steve Tadelis – presentation – 'Algorithm Collusion' available online: [http://www.cresse.info/uploadfiles/2017\\_sps5\\_pr2.pdf](http://www.cresse.info/uploadfiles/2017_sps5_pr2.pdf)

<sup>15</sup> Kai-Uwe Kühn and Steve Tadelis 'Algorithmic Collusion' – presentation available online: [http://www.cresse.info/uploadfiles/2017\\_sps5\\_pr2.pdf](http://www.cresse.info/uploadfiles/2017_sps5_pr2.pdf); Ulrich Schwalbe, 'Algorithms, Machine Learning, and Collusion' (June 2018) Working paper.

and momentum to tackle the policy issues underlying tacit algorithmic collusion. Indeed, the criticism reveals the widening divide between the law and market realities confronted by enforcers and courts on the one hand, and this economic viewpoint on the other hand.

In Part I, we outline the theory and the way pricing algorithms, in specific market conditions, may foster conscious parallelism.

Parts II and III next consider two areas that have attracted recent attention. In Part II, we tackle the instability of tacit collusion. Some argue, that absent some 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. The argument goes that this reality should subject “facilitated tacit collusion” to the key EU antitrust law -- Article 101 TFEU -- and U.S. antitrust provision -- Section 1 of the Sherman Act--and resolve concerns as to parallel behavior that may seemingly escape antitrust scrutiny.

Here we see how some economic observations 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. Absent evidence of any agreement, the enforcers and courts say the tacit collusion is legal. Because the conduct is otherwise legal, the primary mechanism to prevent tacit collusion is merger review. Enforcers, when appraising proposed acquisitions, may block mergers that significantly increase the risk of tacit collusion. They expect “industry awareness” to allow conscious parallelism to materialize post-merger without any illicit communications. To put it simply, enforcers and antitrust plaintiffs search hard for evidence of express collusion and communication. But they and courts ultimately recognize that parallel behavior can arise without communications, and thus comfortably occur within the zone of legality. Indeed, the “pure” model of tacit collusion happens with enough frequency that neither the EU nor US law presume any illicit communication.

So, if this debate was simmering before online commerce and rise of pricing algorithms, the debate has recently become quite heated over the feasibility of algorithmic tacit collusion. If the algorithms cannot communicate with each other, some argue that algorithmic tacit collusion is nothing to lose sleep over. But many enforcers are worried that tacit algorithmic collusion is likelier and harder to detect. So 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 different firms, 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.

Interestingly, enterprising 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, the findings suggest that competition authorities have reasonable grounds to be concerned about algorithmic tacit collusion.

This issue is both timely and important. If an antitrust agency accepts the view that tacit collusion is impossible without human communications, then it need not assess the risk of algorithmic tacit collusion. 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 won't develop algorithmic tacit collusion incubators or conduct market inquiries. It won't 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.<sup>16</sup> In short, the agency would continue with its leniency program for price fixers<sup>17</sup> and sniff out cases where humans still conspire.

Second, the agency's merger review will remain incomplete. A primary way to deter tacit collusion is merger review. The 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 U.S. Department of Justice Antitrust Division, "*the merger occurs and s\*\*\* happens.*" Not surprisingly merger review in recent decades has primarily focused on unilateral effects,<sup>18</sup> which is relatively easier to model and estimate. But 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.<sup>19</sup> 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

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<sup>16</sup> Harrington Jr, Joseph E., Developing Competition Law for Collusion by Autonomous Price-Setting Agents (August 22, 2017). Available at SSRN: <https://ssrn.com/abstract=3037818>

<sup>17</sup> <https://www.justice.gov/atr/leniency-program>.

<sup>18</sup> See, e.g., Malcolm B. Coate, The Merger Process in the Federal Trade Commission from 1989 to 2016 (Apr. 18, 2017) (identifying for FTC mergers a trend toward unilateral effects analysis and increase in efficiency findings after 1994, although dropping for challenged mergers after 2004).

<sup>19</sup> Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 17 (16 May 2017) (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 Group Ltd. v. Brown & Williamson Tobacco Corp.*, 509 U.S. 209 (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"); R. S. Khemani and D. M. Shapiro, 'Glossary of Industrial Organisation Economics and Competition Law'. Paris Organisation for Economic Co-operation and Development, 1993, available at <http://www.oecd.org/dataoecd/8/61/2376087.pdf>.

showing that firms have not acted independently from each other (the so-called ‘meeting of the minds’).’’<sup>20</sup>

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.”<sup>21</sup> With the industry-wide use of computer algorithms and artificial intelligence, the concern is that algorithmic tacit collusion can arise in markets where 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.*<sup>22</sup>

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).<sup>23</sup>

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<sup>20</sup> Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 17 (16 May 2017).

<sup>21</sup> Para 81: Big Data: Bringing Competition Policy To The Digital Era, DAF/COMP(2016)14 (27 Oct. 2016), [https://one.oecd.org/document/DAF/COMP\(2016\)14/en/pdf](https://one.oecd.org/document/DAF/COMP(2016)14/en/pdf)

<sup>22</sup> Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 49-50 (16 May 2017).

<sup>23</sup> ‘Competition 2018’ The Twenty-second Biennial Report by the German Monopolies Commission (Monopolkommission); German-French 2018 joint project on algorithms and their implications on competition - [https://www.bundeskartellamt.de/SharedDocs/Meldung/EN/Pressemitteilungen/2018/19\\_06\\_2018\\_Algorithmen.htm](https://www.bundeskartellamt.de/SharedDocs/Meldung/EN/Pressemitteilungen/2018/19_06_2018_Algorithmen.htm)]; Algorithms and Collusion - Note from Italy, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)18, at 2 (2 June 2017); UK CMA ‘Pricing algorithms - Economic working paper on the use of algorithms to facilitate collusion and personalised pricing’ 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

Algorithmic tacit collusion - that is, the use of algorithms to execute unilateral and rational reaction to market characteristics which reflects interdependence - will not affect every (or even most) markets. As *Virtual Competition* explores, one would expect it 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 key terms of sale, and any deviations from the current equilibrium.<sup>24</sup> 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."<sup>25</sup> 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.*<sup>26</sup>

A *second* important market condition is that once deviation (e.g., discounting) is detected, a credible deterrent mechanism exists.<sup>27</sup> Unique to an algorithmic environment is the speed of

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place in an online context where price monitoring and response can happen particularly quickly." Available online: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/746353/Algorithm\\_s\\_econ\\_report.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746353/Algorithm_s_econ_report.pdf); OECD resources on Algorithms and collusion: <http://www.oecd.org/competition/algorithms-and-collusion.htm>; On the ACCC approach, see for example: <https://www.accc.gov.au/speech/the-accc's-approach-to-colluding-robots>; The Israel Antitrust Authority consultation paper 2018; The U.K. House of Lords - Para 178 & 179, <https://www.publications.parliament.uk/pa/ld201516/ldselect/ldcom/129/12908.htm>;

<sup>24</sup> Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings (2004/C 31/ 03), para 41; Algorithms and Collusion - Note from Singapore, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)24, at 2 (31 May 2017).

<sup>25</sup> Algorithms and Collusion - Note from EU, *supra* note, at ¶ 33.

<sup>26</sup> Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 20 (16 May 2017).

<sup>27</sup> Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings (2004/C 31/ 03), para 41 [EC Merger Guidelines]; Algorithms and Collusion - Note by the European Commission, submitted for the OECD Competition Committee Hearings on 21-23 June 2017,

retaliation.<sup>28</sup> Computers can rapidly police deviations, and calculate the profit implications of myriad moves and counter-moves to punish deviations.<sup>29</sup> 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.<sup>30</sup> 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."<sup>31</sup> Noteworthy are observations made by the European Commission 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 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.<sup>32</sup>*

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

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DAF/COMP/WD(2017)12, at 8 (14 June 2017) (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").

<sup>28</sup> Contrast this with EC Merger Guidelines, *supra*, para 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.")

<sup>29</sup> Jill Priluck, 'When Bots Collude', *The New Yorker* (April 25 2015), available at <http://www.newyorker.com/business/currency/when-bots-collude>.

<sup>30</sup> Samuel B. Hwang and Sungho Kim, 'Dynamic Pricing Algorithm for E-Commerce', in *Advances in Systems, Computing Sciences and Software Engineering*, Proceedings of SCSS05, Tarek Sobh and Khaled Elleithy, eds. (Dordrecht: Springer, 2006), 149–155; N. Abe and T. Kamba, 'A Web Marketing System with Automatic Pricing', *Computer Networks* 33 (2000): 775–788; L. M. Minga, Y. Q. Fend, and Y. J. Li, 'Dynamic Pricing: E-Commerce-Oriented Price Setting Algorithm', *International Conference on Machine Learning and Cybernetics* 2 (2003).

<sup>31</sup> EC Merger Guidelines (n 6), para 52.

<sup>32</sup> Brussels, 15.9.2016 SWD(2016) 312, Paras 550-551, [http://ec.europa.eu/competition/antitrust/sector\\_inquiry\\_preliminary\\_report\\_en.pdf](http://ec.europa.eu/competition/antitrust/sector_inquiry_preliminary_report_en.pdf).

expected from the coordination.”<sup>33</sup> 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,”<sup>34</sup> and the market in general is characterized by high entry barriers.

A *fourth* condition is that tacit collusion is more profitable than competition. 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.”<sup>35</sup>

When these conditions are present, tacit collusion is likelier.

The stability needed for algorithmic tacit collusion is enhanced by the fact that computer algorithms are unlikely to exhibit human biases.<sup>36</sup> 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.<sup>37</sup> “We’re talking about a velocity of decision-making that isn’t really human,” said Terrell McSweeney, 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.”<sup>38</sup>

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<sup>33</sup> EC Merger Guidelines (n 6), para 41.

<sup>34</sup> Fed. Trade Comm’n & U.S. Dep’t of Justice, Commentary on the Horizontal Merger Guidelines (2006), available at <https://www.justice.gov/atr/file/801216/download>.

<sup>35</sup> Algorithms and Collusion - Note by the European Commission, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)12, at 8 (14 June 2017). 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.” Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 20 (16 May 2017).

<sup>36</sup> EC Merger Guidelines (n 6), para 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.”); Algorithms and Collusion - Note from Singapore, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)24, at 2 (31 May 2017).

<sup>37</sup> Stucke and Ezrachi, ‘How Pricing Bots Could Form Cartels and Make Things More Expensive’, Harvard Business Review (October 27 2016), available at <https://hbr.org/2016/10/how-pricing-bots-could-form-cartels-and-make-things-more-expensive>.

<sup>38</sup> David Lynch, ‘Policing the Digital Cartels’, Financial Times (January 9 2017), available at <http://www.pros.com/about-pros/news/financial-times-policing-digital-cartels/>

To be clear, no bright line exists of when an industry becomes sufficiently concentrated for either express or tacit collusion.<sup>39</sup> Indeed, competition agencies often struggle in predicting when a merger may facilitate tacit collusion. In addition, it is important to stress that the above phenomenon will affect a select number of markets. Still, when the above conditions are present, the risk of tacit collusion is high. Importantly, the nature of electronic markets, the availability of data, the adoption of similar algorithms by key providers, and the stability and transparency they foster, will likely push some markets that were just outside the realm of tacit collusion into interdependence.<sup>40</sup>

Indeed software vendors 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.”<sup>41</sup> As the Italian competition authority observed, “a number of specialized software developers offer solutions than 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.’”<sup>42</sup>

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 (than in a competitive setting), without this triggering antitrust intervention.

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<sup>39</sup> 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 and Valerie Y. Suslow, ‘What Determines Cartel Success?’, *Journal of Economic Literature* (2006) 44(1) at 43-95. EconLit, EBSCOhost (accessed April 6, 2017).

<sup>40</sup> One would expect tacit collusion to be feasible with a larger number of participants than commonly assumed. On the common market assumptions, see generally R. Selten, ‘A Simple Model of Imperfect Competition, Where Four Are Few and Six Are Many’, *International Journal of Game Theory* 2 (1973): 141; Steffen Hucka, Hans-Theo Normannb, and Jörg Oechssler, ‘Two Are Few and Four Are Many: Number Effects in Experimental Oligopolies’, *Journal of Economic Behavior and Organization* (2004) 53(4) 435–446.

<sup>41</sup> <https://www.digitalcommerce360.com/2018/07/09/how-retailers-and-brands-can-avoid-the-race-to-the-bottom-in-online-pricing/>.

<sup>42</sup> Algorithms and Collusion - Note from Italy, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)18, at 3 (2 June 2017).

## II. The (In)stability of Tacit Collusion Absent Communication

Algorithmic tacit collusion should not be seen as pervading the entire digital economy. It will likely 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. They argue that while collusion without communication may be possible, it is highly unlikely. To their mind, the increase in transparency, speed in retaliation, and frequency in contacts are insufficient, even under these market conditions. In markets with more than two companies, some kind of explicit coordination (like communications) is needed to enter and sustain collusion. In extending the consensus that communication facilitates alignment (the exact level of communication needed remains unclear),<sup>43</sup> and that complex market realities would make collusion, and tacit collusion, difficult,<sup>44</sup> they argue that absent communication, tacit collusion is unlikely. Their argument is that “firms are unlikely to develop a mutual understanding over a collusive strategy absent direct communication in the initiation phase.”<sup>45</sup>

According to this view, even in simple markets that exhibit the characteristics outlined in Part I, a coordination problem exists when more than two firms are present. This is so, since the number

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<sup>43</sup> Kai-Uwe Kühn, ‘Fighting Collusion by Regulating Communication Between Firms’ (2001) 16 *Economic Policy* 167; Yu Awaya and Vijay Krishnay ‘On Tacit versus Explicit Collusion’ (2014) Working Paper, Penn State University.

<sup>44</sup> For instance, where the environment is dynamic, demand is uncertain, and competition is not limited to price. See: Edward J. Green, Robert C. Marshall, and Leslie M. Marx ‘Tacit Collusion in Oligopoly’ in Roger D. Blair and D. Daniel Sokol *The Oxford Handbook of International Antitrust Economics*, Volume 2 (OUP, 2014)

<sup>45</sup> David P. Byrne and Nicolas de Roos, Learning to Coordinate: A Study in Retail Gasoline (July 23, 2018), Available at SSRN: <https://ssrn.com/abstract=2570637> or <http://dx.doi.org/10.2139/ssrn.2570637> (noting, but not necessarily agreeing with economic theories of collusion that “presume collusive agreements are initiated through explicit communication, or remain agnostic as to how such an understanding emerges”).

of collusive equilibria present in a repeated game defies simple alignment of price.<sup>46</sup> Accordingly, to increase the likelihood of sustained tacit collusion, one would require some form of communication either to kickstart stable tacit collusion, or to sustain it.<sup>47</sup>

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.<sup>48</sup> 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, in these experiments, tacit collusion was difficult, if not impossible, to reach and sustain.

With the above in mind, these critics have argued that the debate over algorithmic tacit collusion is unwarranted. According to them, 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 tacit algorithmic collusion is unlikely. Indeed, the degree of coordination required to align the algorithms would increase the risk of exposure and civil (and potentially criminal) liability. So, 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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<sup>46</sup> On the role of communications, see: Joseph E. Harrington Jr., Roberto Hernan Gonzalez, Praveen Kujale ‘The relative efficacy of price announcements and express communication for collusion: Experimental findings’ [2016] 128 *Journal of Economic Behavior & Organization*, 251-264; Miguel A. Fonseca and Hans-Theo Normann ‘Explicit vs. tacit collusion—The impact of communication in oligopoly experiments’ [2012] 56/8 *European Economic Review*, 1759-1772; David J. Cooper, Kai-Uwe Kuhn ‘Communication, Renegotiation, and the Scope for Collusion’ [2009] *American Economic Journal: Microeconomics*, 6; Joseph Farrell, Matthew Rabin ‘Cheap talk’ [1996] 10/3 *The Journal of Economic Perspectives*, 103-118; Vincent P Crawford, Joel Sobel ‘Strategic Information Transmission’ [1982] 50/6 *Econometrica* 1431-1451.

<sup>47</sup> 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.’ Miguel A. Fonseca and Hans-Theo Normann ‘Explicit vs. Tacit Collusion – The Impact of Communication in Oligopoly Experiments’ [2012] Heinrich-Heine-Universität Düsseldorf, Department of Economics, available online: [http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche\\_Fakultaet/DICE/Discussion\\_Paper/065\\_Fonseca\\_Normann.pdf](http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche_Fakultaet/DICE/Discussion_Paper/065_Fonseca_Normann.pdf)

<sup>48</sup> See for example: Ulrich Schwalbe ‘Algorithms, Machine Learning, and Collusion’ (June 2018) Working paper

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. 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. Such phenomenon, while dampening price competition, is legal, and will not trigger intervention. As the U.S. 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.*<sup>49</sup>

Both EU and US antitrust law recognizes that anticompetitive “behavior can sometimes be coordinated without any communication or other observable and reprehensible behavior.”<sup>50</sup> 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.”<sup>51</sup> In recognizing this possibility, antitrust plaintiffs in the EU and US can only attack this tacit collusion indirectly. One way is for the Federal Trade Commission to attack practices that facilitate tacit collusion under its broader powers under Section 5 of the FTC Act. Another way is to target mergers that foster tacit collusion, precisely because it can be accomplished without any

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<sup>49</sup> *Brooke Group v. Brown & Williamson Tobacco Corp.*, 509 U.S. 209, 224, 227 (1993) (citing Areeda & Turner ¶ 404; Scherer & Ross 199–208); see also *F.T.C. v. H.J. Heinz Co.*, 246 F.3d 708, 725 (D.C. Cir. 2001) (“Tacit 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.”).

<sup>50</sup> *City of Columbia v. Omni Outdoor Advert., Inc.*, 499 U.S. 365, 396 n. 10 (1991) (quoting 6 P. Areeda, *Antitrust Law* ¶ 1400, at 3–4 (1986)).

<sup>51</sup> *Heinz*, 246 F.3d at 725 (quoting 4 Phillip E. Areeda, Herbert Hovenkamp & John L. Solow, *Antitrust Law* ¶901b2, at 9 (rev. ed. 1998)).

communications or agreement among rivals.<sup>52</sup>

So, 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 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.<sup>53</sup>)

This notion affects both merger review and other antitrust enforcement. In the case of ex ante merger review, the realization that tacit collusion may emerge when market conditions are present, will justify careful scrutiny of proposed transactions that would foster conscious parallelism. In the case of ex-post antitrust enforcement, the realization that tacit collusion may emerge when market conditions are present may provide explanation to 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 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.<sup>54</sup> Courts instead will assume that tacit collusion is likely and will require additional proof which include evidence of illicit communication. 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:

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<sup>52</sup> *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.").

<sup>53</sup> *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.").

<sup>54</sup> 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").

*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.*<sup>55</sup>

It is for the competition agency and private plaintiff to establish that no other explanation for the parallel behavior is present. In doing so, it should also consider whether the market may display the conditions for tacit collusion which could explain the parallel behavior. And so, the case law puts the onus on the competition agency and private antitrust plaintiff to prove the implausibility of rational unilateral reaction to market characteristics.

One example is *CISAC v Commission* where the European General Court quashed a finding by the EU Commission that parallel behavior between collecting societies was the result of illegal collusion with the aim of dividing the market. The Court held that the Commission did not establish, to the requisite legal standard, 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 on a practical and economic level, given the specific conditions of the market, and not the result of a concerted practice.<sup>56</sup> The Court held that “the Commission must show precise and consistent evidence in order to establish the existence of the infringement.”<sup>57</sup> 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.”<sup>58</sup>

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<sup>55</sup> Para 66, *Imperial Chemical Industries (ICI) v Commission (Dyestuffs)* Case 48/69 Court of Justice, [1972] ECR 619, [1972] CMLR 557.

<sup>56</sup> Cases T-442/08 *CISAC v Commission* General Court, [2013] 5 CMLR 15.

<sup>57</sup> *Id.* at para 96.

<sup>58</sup> *Id.* at para 99, citing *Joined Cases T-305/94 etc Limburgse Vinyl Maatschappij and Others v Commission* [1999] ECR II-931).

Thus, the case law accepts that absent proof of collusion or communication, parallel action and tacit collusion may be the only explanation of the market outcome. Consumers may be harmed due to higher prices, yet the law cannot condemn the parallelism as illegal. 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.

One interesting example is the United States Court of Appeals for the Seventh Circuit, which in 2015 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.”<sup>59</sup> 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.<sup>60</sup>*

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. The Seventh Circuit recognized that anti-competitive pricing could arise from purely tacit collusion: “There isn't even evidence that [an employee of the defendant] had ever communicated on any subject with any employee of any of the other defendants.”<sup>61</sup> 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.*

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<sup>59</sup> Richard A. Posner, *Oligopoly and the Antitrust Laws: A Suggested Approach*, 21 STAN. L. REV. 1562, 1574 (1969),

<sup>60</sup> *In re Text Messaging Antitrust Litig.*, 782 F.3d 867, 871-72 (7th Cir. 2015)

<sup>61</sup> *Id.* at 872.

*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?*<sup>62</sup>

So the courts assume that “competitors in concentrated markets watch each other like hawks.”<sup>63</sup> 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.”<sup>64</sup>

So 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 reaching a negative result (dismissing cases) when they should be reaching a positive one (finding liability). While economists doubt the ability to enter and sustain conscious parallelism, the law assumes that it is possible without illicit communicates 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 could infer communications among the competitors. Once the court makes this inference, it is a small step to infer from the unobserved communications -- along with

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<sup>62</sup> *Id.* at 873-74.

<sup>63</sup> *Id.* at 875.

<sup>64</sup> *Id.* at 876.

the observed anticompetitive behavior -- an agreement. Thus, under such economic theory, the distinction between express and tacit collusion would fade as the agencies, antitrust plaintiffs, and courts would assume an agreement whenever observing conscious parallelism with anticompetitive outcomes.<sup>65</sup>

This, of course, would send shivers to the defense bar and their clients. Courts would presume that firms communicated, even when they haven't. 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 that some economists rely upon. 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, the benefit they may attain from parallelism and the avoidance of price wars. Firms that operate over long periods of time on markets benefit from "industry awareness" and understand the interdependence between their actions.<sup>66</sup> 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 laboratory setting and, at the very least, provide a plausible explanation to 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

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<sup>65</sup> One potential rebuttal is that the antitrust plaintiffs should still have to hunt 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 expend time and resources to prove the communication? In the end, tacit collusion, also known as conscious parallelism, would always violate section 1 of the Sherman Act and Article 101.

<sup>66</sup> See for example: Rumina Dhalla and Christine Oliver 'Industry Identity in an Oligopolistic Market and Firms' Responses to Institutional Pressures' (2013) 34/12 Organization Studies 1803; Margaret Peteraf and Mark Shanley 'Getting to Know You: A Theory of Strategic Group Identity' (1997) 18/S1 Strategic Management Journal 165.

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.”<sup>67</sup>

Returning to our discussion of algorithms, the same legal approach applies. So when we raised our third and fourth 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.

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 disguising their communications. (One wonders why more cartels don’t adopt this stealth communication to avoid prosecution.) But because pricing algorithms cannot engage in this “stealth communication,” tacit algorithmic 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 of humans communicating (our first scenario), but also recognize humans and algorithms tacitly colluding (our third scenario) without explicit communications.

But 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, without the stealth human communications, would likely drop. If the prices don’t drop, then one must assume, under

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<sup>67</sup> Comment Of The Federal Trade Commission, 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; *In re High Fructose Corn Syrup Antitrust Litigation*, 295 F.3d. 651, 654 (7th Cir. 2002) (a tacit agreement to fix prices is, “an agreement made without any actual communication among the parties to the agreement”).

this economic theory, that the firms, as in the *Topkins* case in the US<sup>68</sup> and the *Trod* and *GBE* case in the UK,<sup>69</sup> agreed to not only collude but also communicated with each other on the algorithms needed to implement and sustain their collusion. So the level of communications should significantly increase as the firms switch to pricing algorithms. This assumption, however, requires enforcers and plaintiffs to hunt for communications that might not exist (if their theory is wrong).

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

### **III. The (Im)plausibility of Algorithmic 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.

Using the criteria that the courts and agencies have applied for decades to explain why mergers may facilitate tacit collusion (and thus should be enjoined), then the factors outlined in Part I, including the transparency of online markets and speed in responding to prevent the discounting firm from benefitting from the price cut, explain how the rational use of algorithms can increase instances in which tacit collusion is sustained. That use may provide a valid explanation to price alignment, even if that goes beyond the conditions of tacit collusion (for instance, additional sellers on the market). After all, under the current legal regime, a rational and permissible use of

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<sup>68</sup> Plea agreement filed in *United States v. David Topkins*, <https://www.justice.gov/atr/case/us-v-david-topkins> (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).

<sup>69</sup> The UK antitrust authority found in 2016 that Trod Limited and GB eye Limited 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 facilitate their illegal agreement. <https://www.gov.uk/government/news/cma-issues-final-decision-in-online-cartel-case>.

algorithms to unilaterally align prices may indeed establish parallelism in instances where humans may fail to. Importantly, this is not a revolution, but rather an evolution. It will not happen effortlessly nor on all markets.

Some contend that even if tacit collusion without communication is possible in the brick-and-mortar economy, that does not mean it is possible in industries where prices are set by algorithms (and perhaps for some firms humans). The potentially large number of collusive equilibria presented by algorithms will likely decrease the likelihood of alignment in a repeated game – that is, algorithms will unlikely obtain and sustain collusion. In what follows, we consider this argument.

Let us start by stating the obvious. The 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 of algorithms, designed by humans, to offer a superior instrument for optimization of pricing decisions, in markets that may support conscious parallelism. In that respect, one should note the limitations of the pricing algorithm. It will not necessarily change the basic characteristics of every market, nor will it overcome instability which 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 the human will, it is helpful to distinguish between “simple” adaptive algorithms that are programmed to 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 human played a role in appreciating the benefit in parallelism (thus, we have evidence of anticompetitive intent, but not necessarily communications), and instances in which human involvement does not include an attempt to stabilize parallelism on the market. Let us explore both categories.

#### *A. Simple algorithms*

Humans can program adaptive algorithms to reflect a pricing strategy which assumes interdependence on the market or is geared to push toward such interdependence. Humans identify the desirability of parallelism, and the market being ripe for conscious parallelism. Humans 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 pricing decision making and so is 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 human develop an awareness to market dynamic and appreciate the interdependence between the operating firms. As a result, the enforcers and private plaintiffs cannot legally challenge the new equilibrium (absent evidence of express collusion). As the algorithms are used unilaterally and as an extension of the human will, they will not be viewed, under the current antitrust policy, as facilitating practices that taint the behavior as illicit collusion.

Granted, but how likely is tacit algorithmic 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.”<sup>70</sup> They then designed an algorithm-human game, where a human competed against the LECA algorithm for 600 rounds. In each round, the human and algorithm could decide the quantity of a product to produce. They could not otherwise communicate with each other. Nor did 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 Cournot competition game,<sup>71</sup> 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 collusion rose to nearly 100% in rounds 300 to 400. What

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<sup>70</sup> <https://arxiv.org/pdf/1802.08061.pdf>.

<sup>71</sup> <https://www.investopedia.com/terms/c/cournot-competition.asp>.

is interesting is that the time to establish collusion (about 400 rounds) in the algorithm-human experiment was quicker than the human-human collusion (about 800 rounds) experiments. From their experiments, the study's authors concluded that first algorithms can facilitate 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, i.e., 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 one 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. While the gas prices are transparent, there is a lag for rivals to discover the lower price. (The rivals, after all, have to drive around town to monitor gas prices.) 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.”<sup>72</sup> This would be especially 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 speed in responding 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 pricing strategy which would be easy to decipher by competitors. Let us briefly illustrate with two examples:

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

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<sup>72</sup> EC Merger Guidelines (n 6), para 49.

regulation softened, rather than increased, competition.<sup>73</sup> The petrol stations' margins increased by 10% on average following the prices being posted on the government website.<sup>74</sup>

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.<sup>75</sup> 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."<sup>76</sup> The government's transparency unit then transmitted the price data to consumers, with the aim that they could easily find the cheapest petrol nearby. Rather than lowering prices, the enhanced market transparency, one economic study found, 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.<sup>77</sup>

Other studies also suggest an increase in transparency can facilitate tacit collusion.<sup>78</sup>

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<sup>73</sup> Fernando Luco, 'Who Benefits from Information Disclosure? The Case of Retail Gasoline', Working Paper, Department of Economics, Texas A&M University September 28, 2016, available at [https://cf00f56d-a-62cb3a1a-sites.googlegroups.com/site/flucoe/home/Info\\_disclosure.pdf?attachauth=ANoY7colGaf66bKWn0h\\_BnbFaq4kHFB7rYJrb6vZVN6BhIZeTPbNs2LRUOiyuLeAP4jY8YXe3nuDW2dEE2wtLOd0YihxBS-4CB2hgafQqHf5a-uyPyq\\_DIPrThncKi7sNvnvXgXomB\\_Hk3ROwYLv9tZWtIWn5YfDAziA69ARs-8nxOrFEJzac5ULK2lBwGHkIO9QsN9sEdZfUnX1OjUL9J2qE\\_IWdgPuhA%3D%3D&attredirects=0](https://cf00f56d-a-62cb3a1a-sites.googlegroups.com/site/flucoe/home/Info_disclosure.pdf?attachauth=ANoY7colGaf66bKWn0h_BnbFaq4kHFB7rYJrb6vZVN6BhIZeTPbNs2LRUOiyuLeAP4jY8YXe3nuDW2dEE2wtLOd0YihxBS-4CB2hgafQqHf5a-uyPyq_DIPrThncKi7sNvnvXgXomB_Hk3ROwYLv9tZWtIWn5YfDAziA69ARs-8nxOrFEJzac5ULK2lBwGHkIO9QsN9sEdZfUnX1OjUL9J2qE_IWdgPuhA%3D%3D&attredirects=0).

<sup>74</sup> 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)." Ibid.

<sup>75</sup> Ibid.; 'Fuel Sector Inquiry', Final Report by the Bundeskartellamt (May 2011), available at [http://www.bundeskartellamt.de/SharedDocs/Publikation/EN/Sector%20Inquiries/Fuel%20Sector%20Inquiry%20-%20Final%20Report.pdf?\\_\\_blob=publicationFile&v=14](http://www.bundeskartellamt.de/SharedDocs/Publikation/EN/Sector%20Inquiries/Fuel%20Sector%20Inquiry%20-%20Final%20Report.pdf?__blob=publicationFile&v=14). 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."

<sup>76</sup> Ralf Dewenter, Ulrich Heimeshoff, and Hendrik Lüth, 'The Impact of the Market Transparency Unit for Fuels on Gasoline Prices in Germany' (May 2016), available at [http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche\\_Fakultaet/DICE/Discussion\\_Paper/220\\_Dewenter\\_Heimeshoff\\_Lueth.pdf](http://www.dice.hhu.de/fileadmin/redaktion/Fakultaeten/Wirtschaftswissenschaftliche_Fakultaet/DICE/Discussion_Paper/220_Dewenter_Heimeshoff_Lueth.pdf).

<sup>77</sup> Ibid. More generally, we also note another interesting study on the impact of price matching guarantee as stabilizing tacit collusive mechanism in petrol markets: Luís Cabral, Niklas S. Dürr, Dominik Schober and Oliver Woll 'Learning Collusion: Theory and Evidence from a Gasoline Market Price Matching Guarantee' (March 2018)

<sup>78</sup> See, e.g., David P. Byrne and Nicolas de Roos, 'Learning to Coordinate: A Study in Retail Gasoline' (January 19, 2017), available at SSRN: <https://ssrn.com/abstract=2570637> or <http://dx.doi.org/10.2139/ssrn.2570637> (finding the systematic use of prices rather than explicit communication as a tool for tacit coordination); Project Update DNRME 18018-Variation 1: The impact of MyFuelINT on Retail ULP prices in the Northern Territory, Griffith University (May 2018), <http://www.parliament.qld.gov.au/Documents/TableOffice/TabledPapers/2018/5618T565.pdf> (finding "that the MyFuelINT 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.").

First, these outcomes, which make sense under the legal standard, are harder to explain under the “no collusion absent communications” theory. Under the 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, under the economic theory, is implausible, the oligopolists, under the theory, must have been actively communicating to sustain their supra-competitive pricing. They conceivably would have communicated their dissatisfaction to each other after their daily drive.

Rather the result is consistent with the legal acknowledgement of sustained tacit collusion where each competitor watches the others like hawks. To monitor pricing, the petrol station owners in Germany would drive past specified competitor petrol stations several times a day and note their prices. The monitored prices were then fed into the respective oil company’s electronic system. Generally, when one competitor increased petrol price, rivals generally would respond between three to six hours later.<sup>79</sup> Now, with increased transparency from the online pricing, they can monitor and punish instantaneously.

So the increase in pricing wasn’t the likely result of “communications.” Instead it likely reflects tacit collusion, where firms, 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 by discounting. Given the velocity with which the pricing algorithms can adjust, each gas stations 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.,

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<sup>79</sup> Dewenter et al., *supra* note (“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.”).

thirty-day) price announcements, where they wait and see what the competitive response is, to decide whether to raise prices (and to what extent). Computers can have multiple rounds whereby one firm increases prices and the rival computers 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 collusion.

As we shift from a world where rivals drive around town to see the price that their rivals charge to where pricing algorithms can achieve this 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. But absent such threats, the market participants can use pricing algorithms to sustain tacit collusion with higher gains (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 move is unlikely to trigger intervention.

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.<sup>80</sup> 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.<sup>81</sup>

Going a step further, humans may use algorithms in a more aggressive way to decode the strategy used by competing algorithms and adjust accordingly.<sup>82</sup> Depending on the technology used, this

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<sup>80</sup> Price match may create an incentive to follow price increases by the price leader. See: Luís Cabral, Niklas S. Dürr, Dominik Schober and Oliver Woll ‘Learning Collusion: Theory and Evidence from a Gasoline Market Price Matching Guarantee’ (March 2018)

<sup>81</sup> See, e.g., *Ethyl Corp. v. Fed. Trade Comm’n*, 729 F.2d 128, 139-40 (2nd Cir. 1984) (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).

<sup>82</sup> See discussion by Michal Gal ‘Algorithms as Illegal Agreements’ (May 2, 2018). Berkeley Technology Law Journal, Forthcoming. Available at SSRN: <https://ssrn.com/abstract=3171977>, noting that ‘the algorithms is a “recipe for action”, which can be directly or indirectly observed by competitors.’ Also see: Bruno Salcedo ‘Pricing Algorithms and Tacit Collusion’ [2015] available online: <http://brunosalcedo.com/docs/collusion.pdf>

might trigger intervention, although if used unilaterally it remains open to argue that the decoding of information is not to be viewed as communication or facilitating practice but rather as unilateral observation under current laws.<sup>83</sup>

To avoid the need to invest in decoding the competing algorithms, companies may adopt a different approach and use the same provider for their pricing algorithm, or the same provider for their dynamic pricing strategies. At present, such Hub and Spoke use is yet to be prohibited by antitrust law.

Returning to our example, several gas stations operating on a given market, could use the same company for pricing decision making. When the same algorithm, data points and values are used by multiple players, the likelihood for alignment increases. One example is the market for petrol in Rotterdam, the Netherlands, where a number of petrol stations, according to the *Wall Street Journal*, used the same provider - the Danish company a2i Systems - for advanced analytics to determine petrol prices.<sup>84</sup> Importantly, note that the provision by the same company of dynamic pricing services, and the creation of a possible hub-and-spoke relationship, does not clearly infringe competition. 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: "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."<sup>85</sup> 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

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<sup>83</sup> Algorithms and Collusion – Note by the European Commission, submitted for the OECD Competition Committee Hearings on 21–23 June 2017, DAF/COMP/WD(2017)12, at 8 (14 June 2017): "one 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."

<sup>84</sup> Sam Schechner. 'Why Do Gas Station Prices Constantly Change? Blame the Algorithm', Wall Street Journal (May 8 2017), available at <https://www.wsj.com/articles/why-do-gas-station-prices-constantly-change-blame-the-algorithm-1494262674>.

<sup>85</sup> PriceCast Fuel Case Story, available at [http://a2isystems.com/files/pdf/PriceCast%20Fuel%20Case%20Story%20\('15\).pdf](http://a2isystems.com/files/pdf/PriceCast%20Fuel%20Case%20Story%20('15).pdf).

their overall strategy in order to lower the cost of price wars or better yet, to avoid them.”<sup>86</sup> 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.”<sup>87</sup> For the petrol company, a2i Systems notes, this “means millions of Euros” more annually.<sup>88</sup>

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 cartel. That would subject it and the petrol stations to civil liability. Rather, it is about the unilateral use of a decision-making algorithm to soften competition. It is about using it 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 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. (The head of the DOJ in 2018 intimated a potential criminal case that may inform the legality of this practice.<sup>89</sup>) Indeed, it is an ‘incidental’ hub-and-spoke – which while not driven by a cartel agreement, may nonetheless facilitate alignment. The UK Competition and Markets Authority noted this use of algorithmic hub and spoke structure as giving rise to concern.<sup>90</sup> As we indicated in *Virtual Competition*, such incidental hub and spoke, while not indicative of a cartel agreement, could indeed 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

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<sup>86</sup> Id.

<sup>87</sup> Id.

<sup>88</sup> Id.

<sup>89</sup> <https://www.broadcastingcable.com/news/delrahim-criminal-case-against-anti-competitive-search-algorithms-coming>. The head of the 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.”

<sup>90</sup> 2018 UK CMA ‘Pricing algorithms - Economic working paper on the use of algorithms to facilitate collusion and personalised pricing’ Available online: [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/746353/Algorithms\\_econ\\_report.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746353/Algorithms_econ_report.pdf)

manufacturer/distributor agrees with the retailer on what the minimum price should be for the manufacturer's product. 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 voice its displeasure 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.<sup>91</sup>

But pricing algorithms can change that dynamic, to the detriment of consumers. The European Commission found in its e-commerce sector inquiry "the increased use of automatic software applied by retailers for price monitoring and price setting."<sup>92</sup> Many, including the biggest online retailers, are using "pricing algorithms which automatically adapt retail prices to those of competitors."<sup>93</sup> 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 prices, the other retailers will automatically follow. The exposure to antitrust enforcement is reduced, due to the more limited communications.

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 which 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."<sup>94</sup> 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 prices. Thus, even in industries not susceptible to tacit collusion, one can obtain the same effect when manufacturers vertically fix prices with one

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<sup>91</sup> RPM is presumptively illegal in Europe and in some states in the US. [https://www.americanbar.org/content/dam/aba/publications/antitrust\\_law/20160711\\_at160711\\_materials.authcheckdam.pdf](https://www.americanbar.org/content/dam/aba/publications/antitrust_law/20160711_at160711_materials.authcheckdam.pdf); [https://www.americanbar.org/content/dam/aba/publishing/antitrust\\_source/feb14\\_lindsay\\_2\\_20f.pdf](https://www.americanbar.org/content/dam/aba/publishing/antitrust_source/feb14_lindsay_2_20f.pdf). 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. *Leegin Creative Leather Products, Inc. v. PSKS, Inc.*, 551 U.S. 877 (2007).

<sup>92</sup> [http://europa.eu/rapid/press-release\\_IP-18-4601\\_en.htm](http://europa.eu/rapid/press-release_IP-18-4601_en.htm)

<sup>93</sup> [http://europa.eu/rapid/press-release\\_IP-18-4601\\_en.htm](http://europa.eu/rapid/press-release_IP-18-4601_en.htm)

<sup>94</sup> [http://europa.eu/rapid/press-release\\_IP-18-4601\\_en.htm](http://europa.eu/rapid/press-release_IP-18-4601_en.htm)

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 them reflecting the humans' intention, or be the result of industry awareness. 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 they identify conscious parallelism as a superior strategy?

Again, we should start by stressing that the issue is not about algorithms conspiring against humans, but rather whether a self-learning price algorithm, programmed to optimize profit by interacting in a dynamic environment, may identify conscious parallelism as an optimal strategy. The question is whether in future markets, where the majority of dynamic pricing decisions will involve minimal human intervention, market equilibrium may be established above competitive levels – not as a result of collusion, nor as a result of humans appreciating the benefits of tacit collusion (and programming their pricing algorithms accordingly), but rather the result of rational action by independent learning algorithms which take account of various data points.

No doubt, much is still uncertain as to the capacity of future reinforced-learning or deep learning algorithms to reach conscious parallelism with no human intervention. Doubts as to learning algorithms' ability to sustain collusion refer to their increased sophistication which would make alignment difficult. Doubts are also linked to the need and ability of algorithms to establish a hidden channel of communication which could address problems of entering and sustaining collusion.<sup>95</sup>

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<sup>95</sup> For papers dismissing the possibility for algorithm driven tacit collusion see: Ulrich Schwalbe 'Algorithms, Machine

While acknowledging current uncertainty, competition agencies around the world have begun looking into these developments. There is no need to be alarmed, 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:

#### *Outcome 1*

If learning algorithms are incapable of autonomously reaching tacit collusion, humans in markets that tilt toward conscious parallelism, would either train them to achieve that outcome or refrain from using them (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 online 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. The question is whether such use should be condemned by competition law or remain unchallenged.

#### *Outcome 2*

If, on the other hand, self-learning algorithms could solve the coordination problem, through trial and error, with no human intervention, then we face an additional complexity in the form of undetected and unchallenged conscious parallelism. In such scenario, algorithms will be able to learn through experiment and shift from competitive pricing rules to collusive pricing rules and sustain that new equilibrium.

Several groups of economists and computer scientists are exploring this avenue. Research has already shown how, under certain conditions, reinforcement learning can sustain cooperation.<sup>96</sup> Furthermore, learning algorithms were shown to gravitate toward conscious parallelism in simple oligopolistic setting.<sup>97</sup> 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 a simplified environment 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 (Calvano, Calzolari, Denicolò and Pastorello from the University of Bologna, European University Institute and Toulouse School of Economics) that have shown that self-learning algorithms can have the capacity to achieve coordination on the collusive outcome.<sup>98</sup> In experiments with two Q-learning algorithms, 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” (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 pre-

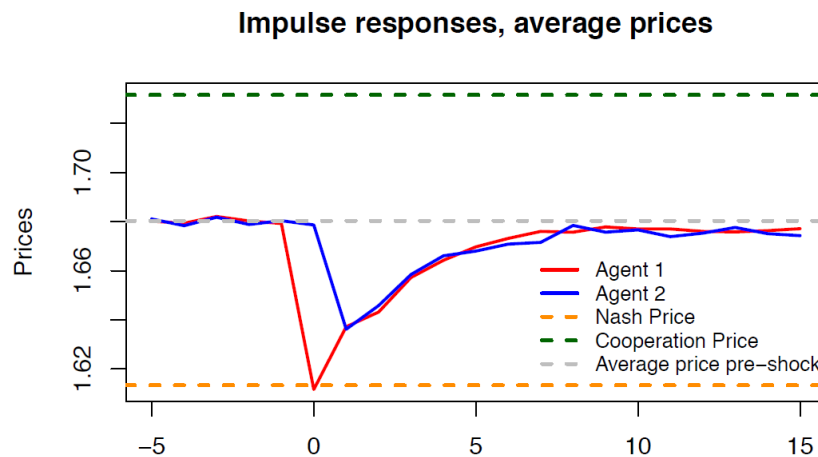
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<sup>96</sup> See for example: Sherief Abdallah, Jean-François Bonnefon, Manuel Cebrian, Jacob W. Crandall, Fatimah Ishowo-Oloko, Mayada Oudah, Iyad Rahwan, Azim Shariff, and Tennom, ‘Cooperating with Machines’ [2018] *Nature Communications*, vol. 9, n. 233; Joel Z. Leibo, Vinicius Zambaldi, Marc Lanctot, Janusz Marecki, Thore Graepel ‘Multi-Agent Reinforcement Learning in Sequential Social Dilemmas’ available online: <https://arxiv.org/pdf/1702.03037.pdf> (analysing fruit gathering and wolfpack hunting game and illustrating conflict emergence and dilemmas affecting cooperation).

<sup>97</sup> Timo Klein ‘Assessing autonomous algorithmic collusion: Q-learning under sequential pricing’ Amsterdam Center for Law & Economics Working Paper No. 2018-05; Gerald Tesauro, Jeffrey O. Kephart ‘Pricing in Agent Economies Using Multi-Agent Q-Learning’ [2002] *5/3 Autonomous Agents and Multi-Agent Systems*, 289–304.

<sup>98</sup> Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò and Sergio Pastorello ‘Algorithmic Pricing: What Implications for Competition Policy?’ University of Bologna - CEPR, Toulouse School of Economics’ June 27th, 2018

existing price level which represents the tacit collusive equilibrium (which is above the competitive price, but below the monopolistic (cooperation) price).



Source: Calvano, Calzolari, Denicolò and Pastorello ‘Q-Learning to cooperate’<sup>99</sup>

In an extension of that experiment, the same group of scholars used three Q-learning algorithms (that is, more than what some argue is possible without communications) in a rich price environment. The group reported that it continued to observe conscious parallelism and increased profitability, with short learning times. Work now continues in complex environments - with increased and changing numbers of algorithms, increased sophistication of algorithms, and increased price levels.

Needless to say, these are still early days in the development of AI and its application to pricing decisions. Uncertainty still 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 effects of increased algorithm complexity.<sup>100</sup> Furthermore, developments in the ability of algorithms to signal,<sup>101</sup> monitor, decode and communicate in stealth mode,<sup>102</sup> will affect any future equilibria.

<sup>99</sup> Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò, Sergio Pastorello, ‘Q-Learning to Cooperate’ presented at the NBER event on ‘Economics of Artificial Intelligence’ September 13-14, 2018

<sup>100</sup> Mary McGlohon and Sandip Sen ‘Learning to cooperate in multi-agent systems by combining Q-learning and evolutionary strategy’ The University of Tulsa, Available online: <http://www.cs.cmu.edu/~mmcgloho/pubs/wclc.pdf>

<sup>101</sup> Jacob W. Crandall, Mayada Oudah, Tennom, Fatimah Ishowo-Oloko, Sherief Abdallah, Jean-François Bonnefon, Manuel Cebrian, Azim Shariff, Michael A. Goodrich & Iyad Rahwan ‘Cooperating with Machines’ Nature Communications, Available online: <https://www.nature.com/articles/s41467-017-02597-8>; Also note discussion by Michal Gal, note 73 above.

<sup>102</sup> Martín Abadi and David G. Andersen ‘Learning to Protect Communications with Adversarial Neural

But we encourage researchers to continue to develop algorithmic tacit collusion incubators that model rich and realistic environments. What would be also interesting is if enforcers (or scholars) could use algorithms deployed in the field to see pricing levels (and margins) for particular products. It might be of interest if the agency could inquire how algorithms responded when one competitor exited (or entered) the market place (perhaps informing future merger review).

#### **IV. Recommendations**

So why does this debate matter? Pricing algorithm suppliers 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. 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 enforcement that may enable the attainment of higher profits (without illegally colluding).

That emerging gap merits closer consideration by competition agencies. But tacit collusion can be hard to detect. 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."<sup>103</sup> Likewise, the U.K. 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."<sup>104</sup> Even if detected, competition agencies, under current law, are limited in challenging tacit collusion.

So where does this leave us?

If one accepts tacit coordination as a material risk in some susceptible industries, then the competition agencies must develop tools to assess (and deter) this risk.<sup>105</sup> No doubt enforcement

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Cryptography' arXiv:1610.06918, available online: <https://arxiv.org/abs/1610.06918>

<sup>103</sup> Algorithms and Competition, Bundeskartellamt 18th Conference on Competition, Berlin, 16 March 2017. [https://ec.europa.eu/commission/commissioners/2014-2019/vestager/announcements/bundeskartellamt-18th-conference-competition-berlin-16-march-2017\\_en](https://ec.europa.eu/commission/commissioners/2014-2019/vestager/announcements/bundeskartellamt-18th-conference-competition-berlin-16-march-2017_en)

<sup>104</sup> Algorithms and Collusion - Note from the United Kingdom, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)19, at 12 (30 May 2017).

<sup>105</sup> Algorithms and Collusion - Note by the European Commission, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)12, at 9 (14 June 2017); Algorithms and Collusion - Note by the United States, submitted for the OECD Competition Committee Hearings on 21-23 June 2017,

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 and 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 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 tacit algorithmic collusion?

First is to better understand the risks of algorithmic collusion. The French and German antitrust agencies announced in June 2018 the launch of a joint research project to investigate algorithms and their implications on competition. During the coming months, the authorities will develop a typology of algorithms and study their potential anti-competitive effects. They will also assess algorithms' detection and examination. The European Commission has also announced a consultation process with a view towards shaping competition policy in the era of digitization. Thus, the US 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. Competition authorities should 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 undesirable developments in competition. 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.<sup>106</sup>

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DAF/COMP/WD(2017)41, at 6 (26 May 2017); Algorithms and Collusion - Note from the United Kingdom, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)19, at 11 (30 May 2017).

<sup>106</sup> Biennial Report of the Monopolies Commission under § 44(1) ARC, 3 July 2018.

Competition agencies should also have dedicated teams dealing with algorithmic collusion and other issues that Big Data and AI present to competition enforcement. Australia's Competition Authority (ACCC), for example, has a Data Analytics Unit.

Second is to improve the agency's tools in detecting collusion. Collusion whether actual or tacit is already difficult to detect. In a market dominated by algorithms, absent a natural experiment or counterfactual (such as a similar market without algorithms), enforcers may not readily discern whether the market price is the result of artificial intervention or natural dynamics: the dynamic price may be the only market price. One key tool that we discuss elsewhere is developing Algorithmic Collusion Incubators, which enables competition officials to test under what conditions collusion occurs, and the effects and likelihood of different counter-measures to destabilize conscious parallelism.<sup>107</sup>

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

- Reversal of the burden 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 algorithms are present, and the risk of tacit algorithmic 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 potentially also in 4 to 3 or even in 5 to 4, and to reconsider the approach to conglomerate mergers when tacit collusion can be facilitated by multimarket contacts.<sup>108</sup>

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<sup>107</sup> <https://www.oecd.org/competition/algorithms-and-collusion.htm>.

<sup>108</sup> Algorithms and Collusion - Background Note by the Secretariat, submitted for the OECD Competition Committee Hearings on 21-23 June 2017, DAF/COMP/WD(2017)4, at 40 (16 May 2017).

This may also require a distinction between the approach to human and algorithmic tacit collusion. It will likely require a refined approach which identify instances in which the use of algorithms may be caught as facilitating practice, signaling or communication.

## Conclusion

Enforcers and policymakers increasingly recognize that the current antitrust enforcement toolbox is limited in effectively deterring algorithmic tacit collusion.<sup>109</sup> It may also be misaligned with the true ability of markets to support tacit collusion, allowing for facilitating tactics to remain under the enforcement radar screen.

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, as part of the everlasting adjustment of competition enforcement 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 optimisation* is used as code for tacit collusion's supra-competitive profits.

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 policymakers 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 us.

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<sup>109</sup> John Naughton, 'How do you throw the book at an algorithm?', The Guardian (December 4 2016), available at <https://www.theguardian.com/commentisfree/2016/dec/04/how-do-you-throw-book-at-an-algorithm-internet-big-data>.