Economist's Note

What Do We Now Know about 'Machine Collusion'

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I. Introduction

The possibility and prevalence of machine-based price collusion are hotly debated. The pessimistic view is that the use of self-leaning pricing algorithms poses a significant threat to competition, which warrants urgent attention. To others, this is an exaggerated hypothesis with no evidence or real-world examples, and which in any case can be handled with the tools already available to competition regulators. This note addresses three central questions by reviewing the case for and evidence on algorithmic price collusion: (i) Is machine-based collusion possible? (ii) Is it likely to be widespread? and (iii) Can the current law cope?

Key Points

- Some legal academics have claimed that 'machine collusion'—tacit collusion generated by self-learning pricing algorithms without human involvement—is a real threat that will go uncheck by current antitrust.
- Half a decade after these claims received wide publicity only a handful experimental desktop computer simulations with uncertain real-world relevance which suggest at best the possibility of machine collusion.
- The prospect of machine collusion is more limited and the law more adaptable than this literature assumed.

II. Project fear

The debate over algorithmic collusion was kick started by legal academics Ezrachi and Stuck,[1] Mehra,[2] and Gal.[3] Their thesis is that the use of pricing algorithms is widespread, they can be used to facilitate and expand collusive pricing and enable a new breed of autonomous machine-generated tacit collusion without the need for human cooperation. This combined with the 'oligopoly gap' in current antitrust which permits tacit collusion, creates the possibility that machine-based cartels will go undetected and unpunished. To emphasise the severity of the problem Ezrachi and Stucke warn that algorithm systems mark the 'end of competition as we know it'.[4]

There is no quibble with the proposition that algorithms can facilitate anticompetitive pricing. Indeed, the observation is trivial since all pricing, and online and computer-based activities, are driven by algorithms. Further, firms can and have employed algorithms to facilitate collusion. The issue here is whether algorithms can make express and tacit collusion easier and more prevalent, or simply facilitate and better disguise collusion in industries that would have colluded anyway. Ezrachi and Stucke express the (unsupported) view that 'pricing algorithms can spread tacit collusion beyond duopolies to markets with five or six large firms'.[5] This claim is unexceptional since cartels prosecuted by the European Commission typically consist of more than two firms and an average of six firms.

The novel aspect of the current debate is the possibility of 'machine collusion' unassisted by human action. This threat comes from so-called self-learning or reinforced learning algorithms, which are programmed to maximise the net present value of profits and autonomously decide the prices/margins that will achieve this taking into account the prices and pricing reactions of competitors. These purportedly can collude without human monitoring and inter-firm communications to set cartel-type

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1 Ariel Ezrachi and Maurice E. Stucke, *Virtual Competition: The promise and perils of the Algorithm-driven economy* (Cambridge Mass.:Harvard University Press, 2016).

2 Salil K. Mehra, 'Antitrust and the Robo-Seller: Competition in the Time of Algorithms' (2016) 100 Minnesota Law Review 1323.

3 Michal S. Gal, 'Algorithms as Facilitating Practices' (2019) 34 Berkeley Technology Law Journal 67.

4 Ezrachi and Stucke (n. 1) 233.

5 Ariel Ezrachi and Maurice E. Stucke, 'Algorithmic Collusion: Problems and Counter-Measures – Note' OECD Roundtable on Algorithms and Collusion, 21-23 June 2017, 233.

prices. This not only extends collusion but undermines the effectiveness of anti-cartel laws based on an agreement between humans.

III. The evidence on 'machine collusion'

Given the claims made about the prospects and ill-effects of machine-based collusion, one would have thought this would have been backed by strong evidence. This is not the case. There is no real-world evidence, no example yet, and no antitrust case that establishes that self-learning pricing algorithms have colluded let alone increased the prospect of collusion across the economy.

In the half-decade since the concerns about machine collusion received widespread attention, there have only been a handful of experimental computer simulations of self-learning algorithms.[6] These use relatively simple QL algorithms and a set of restrictive assumptions such as a duopoly selling a homogeneous product, transparent prices where there is no wholesale prices, discounts or rebates, passive consumers' reaction to prices, and 'perfect and symmetric information at zero cost and zero delays'. This research confirms the theoretical possibility of collusive pricing without direct communications between the algorithms after a considerable learning period. The Calvano *et al* model, which is the most thorough analysis to date, requires 850,000 periods (repetitions) to learn to collude 'tacitly'. Which to put this in perspective if prices changed once a day would take 2,500 years to achieve a collusive outcome. The fact that a model has simplifying assumptions is not a strong criticism (at least to an economist). Rather, the central point is that these models do not reflect the complexity of the real-world pricing and hence their likely commercial feasibility and effects.[7] For example, the QL algorithms used by these simulations are not used commercially by pricing software. There is other similar evidence that algorithms can destabilise collusive tendencies.[8]

Despite this limited experimental research, the legal proponents of widespread algorithmic collusion see this as evidence 'proving' the real prospect of machine-based algorithmic collusion. For example, Michal Gal states: 'The possibility of collusion is real. This has been proven both theoretically and empirically'[9] referring to the then unpublished experimental research of Emilio Calvano and his colleagues. Unfortunately, such confirmation bias typifies this strand of legal research. It stands in stark contrast to the more measured and tentative conclusions of those generating the experimental evidence. Calvano *et al* conclude that '[a]t present, we simply do not know enough about AP [algorithms pricing] to make definitive policy recommendations'.[10] Descamps, Klein, and Shier in their survey of the area conclude that there is 'no evidence other than computer simulations in a 'controlled laboratory elaborate settings' and that 'many practical limitations for ... autonomous collusion remain'.[11] The idea of machines colluding without human knowledge is according to EU Competition Commissioner Vestager 'science fiction'.[12] This is not to say that in the future self-learning algorithms can collude, as we know yesterday's science fiction is often today's reality.

The legal academic literature also cites as 'evidence' several recent antitrust decisions. In all these cases the pricing algorithms were deployed by the parties to facilitate their human 'agreement' to collude or implement otherwise anticompetitive conduct, and therefore are not examples of machine collusion. In *Trod Ltd/GBE*[13] the UK Competition and Market Authority (CMA) fined online sellers of posters and frames for using automated off-the-shelf re-pricing software to monitor and adjust their prices on Amazon Marketplace. In *Eturas*[14] travel agents used algorithms to set prices through an online booking platform. The European Commission's *Asus*[15] and the

6 Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò and Sergio Pastorello, (2020) 'Artificial Intelligence, Algorithmic Pricing and Collusion' (2020) 110 American Economic Review 3267; Timo Klein, 'Autonomous Algorithmic Collusion: Q-Learning Under Sequential Pricing' (2021) 52 RAND Journal of Economics 538; Zach Y. Brown and Alexander MacKay 'Competition in Pricing Algorithms' NBER Working Paper 28860 (2020); Ibrahim Abada and Xavier Lambin 'Artificial intelligence: Can seemingly collusive outcomes be avoided? February 15 2020; Bruno Salcedo, 'Pricing Algorithms and Tacit Collusion', Working Paper (2015).

7 This is the point stressed in *Algorithms and Competition*, Joint Report of the Autorité de la Concurrence and Bundeskartellamt (2019) 21 & 50/1.

8 Jeanine Miklós-Thal and Catherine Tucker, 'Collusion by Algorithm: Does Better Demand Prediction Facilitate Coordination Between Sellers?' (2019) 65 Management Science 1455.

9 Michal Gal, 'Algorithms & Competition Law: Interview of Michal Gal by Thibault Schrepel' E-Competitions Interviews Series 14 May 2020.

10 Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò and Sergio Pastorello, 'Artificial Intelligence, Algorithmic Pricing and Collusion' CEPR Discussion Paper 13405 (2019) 169. SSRN: https://ssrn.com/abstract=3304991 (date accessed 10 November 2021).

11 Ambroise Descamps, Timo Klein and Gareth Shier, 'Algorithms and Competition: The latest theory and evidence, (2021) 20 Competition Law Journal 32.

12 Margarethe Vestager, Speech at the Bunderskartellampt 18th Conference on Competition, Berlin, 16 March 2017.

13 Decision of the Competition and Markets Authority, *Online sales posters and frames*, Case 50223, 12 August 2016. Also see the similar US 'posters' decision often cited *United States of America v David Topkins*, Plea Agreement, Department of Justice, Antitrust Division, No. CR 15-00201 WHO.

14 Case C-74/14 *Eturas' UAB and Others v Lietuvos Respublikos konkurencijos taryba* EU:C:2016:42, Judgment of the Court, 21 Jan 2016. Another example of the use algorithms to facilitate collusion is *United States v Airline Tariff Publ'g Co.,* 836 F. Supp. 9 (D.D.C. 1993).

15 European Commission Press Release, *Antitrust: Commission fines four consumer electronics manufacturers for fixing online resale prices*, Cases

CMA's *Casio*[16] decisions found that pricing algorithms had been used to enforce resale price maintenance. The UK energy sectoral regulator Ofgem's competition law decision fining two energy suppliers, owned by childhood friends and with cross-holdings in their respective companies, for using an algorithm to facilitate their market/-customer sharing agreement in contravention of Chapter I of the Competition Act 1998 (equivalent to Article 101 TFEU).[17] It is noteworthy that the CMA also fined the developer of the algorithmic software. Of course, the fact that machine-based collusion has not yet been prosecuted does not establish that it has not occurred or will not arise, since the law is currently only prosecuting cases involving human action.

IV. The theory

As Gal above has declared the 'theory' proves that machine-based collusion is a real threat. A theory cannot prove this, but it is important to understand what theory is being used and its limitations.

For a start, much of the theory is informal and argumentative. It is not based on an understanding of algorithms, computer simulations, and their commercial applications and limitations but a simplistic application of Stigler's conditions for collusive pricing.[18] According to Stigler the prospect that firms will successfully collude is a function of their ability to monitor their competitors' prices and penalise defectors. Pricing algorithms can do both high speeds. Therefore, so it is argued, it follows that they make tacit collusion easier, and therefore more prevalent and durable. However, this ignores the fact that the speed making price changes alone is not the governing factor especially since prices often do not change that frequently, and that transparent prices facilitate collusion irrespective of the existence of self-learning algorithms. It also presumes that self-learning algorithms in practice can easily collude, which has not yet been established.

Secondly, the proponents of machine collusion are vague as to which industries are susceptible to self-learning algorithmic collusion. If one looks at the empirical evidence the predominant cartel is the sellers' cartel for intermediate manufacturing inputs or components. These are business-to-business operations between sophisticated direct purchasers. Often these cartels have been formed in response to structural problems in the industry such as excess capacity and declining prices due to technological advances and/or entry, and where discounts and rebates are commonplace; factors that give rise to an instability that would make self-learning algorithmic collusion unlikely. Pricing algorithms are mostly used for airline, hotel, and events bookings, Uber-like services, petrol station gasoline sales, and online retail sales. Many of these take the form of dynamic pricing of non-storable products or services (hotel rooms; airline seats). Ezrachi and Stucke focus on retail pricing by business-to-consumer e-commerce platforms, which have already been the focus of cartel enforcement actions (see above). These are very different from the traditional sellers' cartels, which have been prosecuted by antitrust authorities. It is, therefore, no surprise that the only (unpublished) empirical analysis of algorithmic collusion comes from bricks-and-mortar German petrol retail outlets in duopoly markets,[19] a sector that has been historically afflicted by allegations of collusive pricing.

Effective sustainable collusion requires the existence of specific structural and behavioural conditions conducive to the cartelisation. While machine-based pricing algorithms may be able to dispense with human and machine communications between rivals, they nonetheless will be confined to industries that are concentrated with significant barriers to entry, transparent pricing, and the other factors typically listed as required for collusion by competition authorities. That is an ill-defined combination of 'plus-factors'. This further limits the sectors at risk and raises the possibility that machine-based collusion merely substitutes for human collusion in industries where the conditions for collusion are ripe. As Ezrachi and Stucke clarify:

> Let us start by stating the obvious. This discussion does not concern 'the rise of the machines' nor the creation of 'evil' algorithms that seek to profit at the expense of consumers. It is a somewhat less exciting debate about the possibility that human-designed algorithms might offer a superior instrument for the optimization of pricing decisions, in markets that may support conscious parallelism. In that respect, one

AT.40465 (Asus), AT.40469 (Denon and Marantz), AT.40181 (Philips) and AT.40182 (Pioneer), decisions of 24 July 2018.

16 Decision of the Competition and Markets Authority, *Digital piano, and digital keyboard sector: anti-competitive practices* 50565-2 (nonconfidential), 8 October 2019. https://www.gov.uk/cma-cases/musical-instruments-and-equipment-suspected-anti-competitive-agreements-50565-2#non-confidential-infringement-decision (date accessed 10 November 2021).

17 OFGEM, *Infringement by Economy Energy, E (Gas and Electricity) and Dyball Associates of Chapter I of the Competition Act 1998 with Respect to an Anticompetitive Agreement*, July 26, 2019.

18 George J. Stigler, 'A Theory of Oligopoly' (1964) 72 Journal of Political Economy 44.

19 Stephani Assad, Robert Clark, Daniel Ershov and Lei Xu, 'Algorithmic Pricing and Competition: Empirical Evidence from the German Retail Gasoline Market', CESifo Working Paper 8521 (2020).

> should note the limits of the pricing algorithm. It will not necessarily change the basic characteristics of every market, nor will it overcome instability that results from lower barriers to entry, maverick companies, or fierce competition. The tool at hand, at times, will amplify the power to monitor and punish in instances when humans see a benefit in sustaining parallel behaviour.[20]

Further, the use of pricing algorithms enables e-commerce platforms to increase their use of price discrimination.[21] However, discriminatory, personalised pricing, and competition based on non-price terms and quality are hostile to successful collusion. Simple economic logic tells us that collusion is more likely where the good is homogeneous and sold at a single transparent price. This is because monitoring divergences from the agreed uniform price for a standardised product is easier and cheaper. Where prices differ among customers for the same product or the product has different quality attributes and prices, then it is hard for pricing algorithms to locate a stable collusive set of prices.

V. Is there a gap in the law?

Machine collusion poses a challenge to the way anti-cartel laws are enforced. This is because the law is based on human agreement and cooperation, whereas self-learning algorithms would if used to collude autonomously set prices without any human agreement. This it is claimed reveals a gap in the law that will allow machine collusion to go unfettered.

This proposition strikes the author as simplistic for several reasons. First, it requires acceptance that the executives of a firm can hand over their pricing decisions to 'pricing bots' over which they have no control and no understanding of the way they set prices, and importantly ignorance of the way these algorithms set prices can be successfully mounted as a legal defence. It is very unlikely that the company's executives will be able to wash their hands of machine collusion by saying that 'it was the machine that done it'. They commissioned the computer scientists to develop the algorithm, purchased the software and handed over their pricing to the self-learning pricing algorithms written for the company. Indeed, if future experimental research shows that self-learning algorithms are likely to lead to industry-wide collusion and legal academics continue to point out the threat of algorithmic collusion, firms deploying these algorithms would have little defence. Moreover, the lengthy pre-launch testing period means that the software developers will know the outcome of a self-learning algorithms before it is launched by the firm. As EU Competition Commissioner Vestager has warned 'companies can't escape responsibility for collusion by hiding behind a computer program':

> They [businesses] may not always know exactly how an automated system will use its algorithms to take decisions. What businesses can – and must – do is to ensure antitrust compliance by design. That means pricing algorithms need to be built in a way that doesn't allow them to collude . . . . And businesses also need to know that when they decide to use an automated system, they will be held responsible for what it does. So they had better know how that system works.[22]

It is also the case the 'gap' in antitrust comes not from the law but the way it is enforced. The European Commission and other national competition authorities prosecute cartels as by-object infringements under Article 101 TFEU and adopt a reactive enforcement policy reliant on whistle-blowers. These practices are not pre-ordained by the law. They could easily be changed by relying more on the 'concerted practices' provision, by-effect prosecutions, and a more proactive enforcement strategy based on digital screening to detect algorithmic collusion. Some competition authorities are already gearing up for this by establishing dedicated digital units.

VI. Conclusion

In conclusion, no evidence, no cases, and a retreat by the academic lawyers from the more grandiose claims that evil algorithms are taking over the economy, whereas at the same time, many competitions regulators 'digitalizing' themselves to ensure that the law and its enforcement can address the threat posed of algorithmic and machine collusion should it eventuate.

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20 Ariel Ezrachi and Maurice E. Stucke, 'Sustainable and Unchallenged Algorithmic Tacit Collusion' (2020) 17 Northwestern Journal of Technology and Intellectual Property 217, 241.

21 Ezrachi and Stucke (n. 1) chapter 4.

22 Vestager (n. 12).