ARTIFICIAL INTELLIGENCE AND THE LAW

Second Revised Edition

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CHAPTER 19

AI AND ANTITRUST: BETWEEN COLLISION AND COLLUSION

Christof Koolen* and Bruno Van den Bosch**

1. INTRODUCTION

1. The algorithmic age is near. Undertakings increasingly rely on artificial intelligence (AI) to steer their commercial behaviour on the market. Contrary to traditional business models, human involvement is reduced to a minimum. For instance, the idea of a bank manager who manually checks and approves loan applications belongs to the past. Instead, firms increasingly derive value from algorithms and automation. AI sets the price on e-commerce platforms, AI recommends songs on Spotify or viewing recommendations on Netflix, and AI determines which consumers qualify for a bank loan. While the age of machine intelligence was ushered in by large entities such as Google, Amazon, Facebook, and Alibaba, smaller entities are now following suit.

Traditional business models are gradually becoming intertwined with digital components in the form of software and code. By tapping into the potential of big data and by subsequently involving AI-based models in a commercial setting, it becomes possible to revolutionise how entrepreneurs conduct business. More particularly, the value proposition offered by AI revolves among others around increased accuracy, detailed insights into the customer base, and the ability to tailor products and services to these insights accordingly. When contrasting traditional processes against AI-driven processes, it quickly becomes clear that an algorithmic approach to commerce offers distinct advantages over a non-algorithmic approach.

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2. It follows that AI has significant potential to disrupt the current means of doing business and the ability to compete on the market. This triggers the following question: *are AI and competition law on a collision course*? This chapter demonstrates that this is true to at least some extent. At the same time, the contribution also argues that some of the difficulties stem from an incomplete understanding of the inner workings of AI and relate to AI taking legal scholars into unfamiliar territory. All in all, algorithms do indeed create new challenges for both national and European competition authorities – tasked with assessing anticompetitive agreements under Article 101 TFEU, curbing abusive market behaviour pursuant to Article 102 TFEU, and conducting merger control[1] under the EU Merger Regulation. However, not all of these challenges are insurmountable.

3. This chapter focusses on the current implications of AI for the field of EU competition law *sensu stricto* (Articles 101 and 102 TFEU) and provides a comprehensive overview of the current state of the art. The underlying theme within this contribution is 'predictability': while AI is often said to function as a black box (i.e., data goes in and solutions come out, but the intermediary steps between input and output are unclear), it should be borne in mind that algorithms essentially perform a set of steps that any individual could also carry out himself. The ability to retrace these steps offers some solace to competition authorities put in a position to judge the anticompetitive nature of machine intelligence, which is affecting the competitive dynamics of a given market.

In terms of content, the chapter adheres to a threefold structure. Firstly, we will focus on *competition for AI*. This part provides the necessary context by illustrating how market dynamics are changing due to the increased possibility to implement AI within undertakings' business models (part 2). We will then discuss *competition with AI*. This part addresses how undertakings currently make use of AI. It explains what AI does and does not do for undertakings. Real-world use cases serve as a point of reference to assess how firms compete against each other and how competition law is adapted to deal with AI-based collusion and abuses of dominance (part 3). Subsequently, we will focus on *AI for competition*. This part explains how the enforcement angle of competition law can also be changed by algorithms. AI not only proves beneficial for undertakings, but also for

1 The intersection between artificial intelligence and competition law contains a broad range of subtopics. To bring focus to this book chapter, the choice was made to study Articles 101 and 102 TFEU in particular. Readers interested in EU merger control and algorithms may consider the following literature recommendations: V. Egerton-Doyle and J. Ford, 'Algorithms, Big Data, and Merger Control' in A. Portuese (ed.), *Algorithmic Antitrust* (Cham: Springer, 2022), p. 87; N. Maier, 'Closeness of Substitution for 'Big Data' in Merger Control', *Journal of European Competition Law & Practice* 2019, vol. 10, no. 4, p. 246; J. Modrall, 'Big Data and Merger Control in the EU', *Journal of European Competition Law & Practice* 2018, vol. 9, no. 9, p. 569; B. Holles de Peyer, 'EU Merger Control and Big Data', *Journal of Competition Law & Economics* 2017, vol. 13, no. 4, p. 767.

competition authorities, for instance, in the form of pattern recognition algorithms (part 4). We will end this chapter with some concluding remarks (part 5).

4. The contribution is novel in two ways. Firstly, it comprehensively scrutinises the existing literature on AI and competition law and presents the main findings of the different strands of literature in one concise overview. Secondly, it aspires to deliver added value on top of the existing body of scholarship by remaining grounded in reality. A lot of hype surrounds AI nowadays, and our objective is to add nuance to the debate and to contextualize where necessary, in addition to downplaying some of the buzz surrounding AI. In concluding the topic of AI and competition law, the chapter puts forward the question whether firms and competition authorities are truly trapped in a competitive legal environment that is at least partially governed by AI.

2. COMPETITION FOR AI – THE MARKET FOR AI SYSTEMS

2.1. THEORY OF COMPETITION

5. Underpinning competition law is the idea that society as a whole is better off when firms compete.[2] A competitive market is theorised to give each individual firm the incentive to keep innovating, to lower prices, and to meet consumer demand in the most efficient manner.[3]

6. To maintain effective competition on a given market, competition law specifically targets several market practices, which are considered harmful to the process of competition.[4] Pursuant to Article 101 TFEU, agreements between undertakings[5], decisions by associations of undertakings[6], and concerted practices[7] are prohibited when they have as their object or effect the prevention, restriction, or distortion of competition within the internal market.[8]

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2 R. Khemani, 'Objectives of Competition Policy' in R. Khemani (ed.), *A Framework for the Design and Implementation of Competition Law and Policy* (Washington, D.C.: World Bank Publications, 1999), p. 2.

3 M. Stucke, 'What is competition?' in D. Zimmer (ed.), *The Goals of Competition Law* (Cheltenham: Edward Elgar Publishing, 2012), p. 33.

4 R. Whish and D. Bailey, *Competition Law,* 8th edn (Oxford: Oxford University Press, 2015), p. 3.

5 CJEU 25 October 1983, no. C-107/82, ECLI:EU:C:1983:293, *AEG-Telefunken*.

6 CJEU 14 July 1972, no. C-48/69, ECLI:EU:C:1972:70, *Dyestuffs*.

7 CJEU 15 September 2005, no. T-325/01, ECLI:EU:T:2005:322, *DaimlerChrysler*.

8 D. Bailey and L. John, *Bellamy & Child: European Union Law of Competition*, 8th edn (Oxford: Oxford University Press, 2018), pp. 87–88; E. Fox and D. Gerard, *EU Competition Law: Cases, Texts and Context* (Cheltenham, Edward Elgar Publishing, 2017), p 33; A. Jones, B. Sufrin and N. Dunne, *EU Competition Law: Test, Cases, and Materials*, 7th edn (Oxford: Oxford University Press, 2019), pp. 137–139; Whish and Bailey, *Competition Law*, pp. 84–85.

This provision specifically precludes competing undertakings from entering into agreements with the aim to fix prices, restrict outputs, share markets, or coordinate their behaviour on the market in general when such an agreement would have an appreciable effect on trade between EU Member States.[9]

Apart from prohibiting anticompetitive agreements between different undertakings, competition law also considers abusive unilateral behaviour to run counter to Article 102 TFEU. Accordingly, any abuse[10] of a dominant position[11] within the internal market shall be prohibited as incompatible with the internal market in so far as it affects trade between EU Member States.[12] This provision is put in place to curb abusive conduct on the market, which can occur by means of leveraging established market power and resources in view of suppressing competition or expanding into other market segments. Typical abuses of dominance caught under Article 102 TFEU include predatory pricing, price discrimination, tying practices, or refusals to supply.

7. The abovementioned aims of competition law have seen extensive coverage in academic scholarship and the core policy objectives underpinning these provisions have been widely accepted.[13] While there is some debate on the scope and reach of competition policy, the normative justifications as to why competition is necessary predominantly revolve around increasing consumer and societal welfare.[14] Although some disagreement exists as to the precise meaning of the phrase 'society being better off as a whole', these discussions have mostly been relegated to the margins.[15] When further addressing the goals of competition law, it should be borne in mind that the early conceptions of antitrust law were mostly aimed at breaking up large economic powers since they were perceived as a threat to core democratic values.[16] Nowadays, however, these

9 Established case law on this topic includes: CJEU 30 June 1966, no. C-56/65, ECLI:EU:C:1966:38, *Société Technique Minière*; CJEU 13 July 1966, nos. C-56/64 and C-58/64, ECLI:EU:C:1966:41, *Consten and Grundig*.

10 CJEU 12 December 1991, no. T-30/89, ECLI:EU:T:1991:70, *Hilti AG*.

11 CJEU 14 February 1978, no. C-27/76, ECLI:EU:C:1978:22, *United Brands*.

12 Bailey and John, *Bellamy & Child*, pp. 859–862; Fox and Gerard, *EU Competition Law*, pp. 159–161; Jones, Sufrin and Dunne, *EU Competition Law*, pp. 277–280; Whish and Bailey, *Competition Law*, pp. 183–184.

13 See, for instance, L. Parret, 'The multiple personalities of EU competition law: time for a comprehensive debate on its objectives' in D. Zimmer (ed.), *The Goals of Competition Law* (Cheltenham: Edward Elgar Publishing, 2012), p. 64 ff.

14 A. Ezrachi, 'EU Competition Law Goals and The Digital Economy', *SSRN Scholarly Papers*, 2018, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3191766, pp. 4–5.

15 L. Kaplow, 'On the choice of welfare standards in competition law' in D. Zimmer (ed.), *The Goals of Competition Law* (Cheltenham: Edward Elgar Publishing, 2012), pp. 3–4 and pp. 18–19: '*For all the debate about the objectives of competition law and, in particular, whether a welfare- based measure should reflect only consumer welfare or encompass total welfare, only modest attention has been given to why the difference matters*'.

16 F. Roosevelt, *The New Deal: Message to Congress on the Concentration of Economic Power*, 29 April 1938, https://publicpolicy.pepperdine.edu/academics/research/faculty-research/new-deal/roosevelt-speeches/fr042938.htm: '*The first truth is that the liberty of a democracy is not safe if the people tolerate the growth of private power to a point where it becomes stronger*

goals have been stretched significantly and, for instance, also address aspects such as sustainability considerations.[17] Nonetheless, the core idea remains the same: competition law aims to foster and protect the process of competition between undertakings.

2.2. THE MARKET FOR AI SYSTEMS

8. From the perspective of an undertaking, facing fierce competition typically implies a reduction in terms of profit margins (i.e., the producer surplus) due to market prices remaining close to marginal costs.[18] Hence, given the need to compete on the market, firms must continuously push for lower prices, better products, increased product choice, or more efficient production methods. This constant strive regularly incites undertakings to engage in anticompetitive behaviour. For instance, competing firms could benefit from coordinating their market conduct with each other by fixing prices at an above-market level or by deciding to stay out of each other's way (i.e., market allocation). Similarly, a firm that maintains a dominant position in a particular market may decide to leverage its established market power to engage in exclusionary[19] (e.g., refusals to supply, exclusive dealing, bundling/tying, predatory pricing, …) or exploitative[20] conduct (e.g., excessive pricing, price discrimination, …).

9. There are several reasons why market conditions are changing following the introduction of AI into undertakings' value chains. One of those reasons is tied to the creation of a new *market for AI systems*.[21] While there is no doubt about the benefits that AI could bring to the market, undertakings often lack the necessary human capital or financial means to create their own AI system. A hospital, for example, would benefit from having access to AI to automatically detect cancer cells in microscopic images.[22] However, developing such a solution

than their democratic state itself. That, in its essence, is fascism – ownership of government by an individual, by a group, or by any other controlling private power'.

17 On this topic, see for instance S. Holmes, 'Climate change, sustainability, and competition law', *Journal of Antitrust Enforcement*, 2020, vol. 8, no. 2, pp. 354–355.

18 Jones, Sufrin and Dunne, *EU Competition Law*, pp. 4–7.

19 Communication from the Commission – Guidance on the Commission's enforcement priorities in applying Article 82 of the EC Treaty to abusive exclusionary conduct by dominant undertakings [2009] OJ C 45/7.

20 M. Botta and K. Wiedemann, 'Exploitative Conducts in Digital Markets: Time for a Discussion after the Facebook Decision', *Journal of European Competition Law & Practice*, 2019, vol. 10, no. 8, p. 465.

21 Proposal for a Regulation of the European Parliament and of the Council laying down harmonized rules on Artificial Intelligence (Artificial Intelligence Act), 2021, COM (2021) 206 final; X, 'New rules for Artificial Intelligence', *European Commission*, 2021, https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_1683.

22 M. Stumpe, 'An Augmented Reality Microscope for Cancer Detection', *Google AI Blog*, 2018, https://ai.googleblog.com/2018/04/an-augmented-reality-microscope.html.

in-house is often not feasible. For those instances, undertakings could rely on AI systems that are offered 'off the shelf'.[23] Such solutions are usually brought to market by dedicated companies and are tailored to a client's specific needs and wants. Other notable examples of pre-build AI models include chatbots and virtual assistants.

At the other side of the spectrum, there are also undertakings that develop their AI in-house. Such an approach not only calls for access to expertise and know-how, but also requires expensive hardware, which is needed to meet the high computational demands of contemporary AI systems.

10. Barring specific situations, it is worth pointing out that the *barriers to entry* into the market for AI systems are relatively low. Basic information on how to code algorithms or on the fundamentals of complex AI models are readily available online.[24] It is also not unusual to find university-level courses on the topic of AI via online learning platforms.

In terms of hardware, AI is known to be extremely resource-intensive due to the lengthy calculations that need to be performed. Evidently, the more computing power is available to the AI, the less time it will take to train the model. Individuals looking to recreationally use AI would incur roughly 3.000 EUR in hardware costs for an entry-level setup. While such a setup will enable users to solve basic tasks, it will fall short when attempting to tackle more sizeable problems. The computational complexity of a task – expressed in terms of computation time and memory space – therefore acts as a constraint on the entry into the market for AI systems.[25] On that note, AI assignments in a commercial setting will generally involve large datasets, implying that consumer-grade hardware is unsuitable for such tasks.[26]

Training data for the AI model might be difficult to come by. While some machine learning repositories offer extensive datasets for free[27], these data will often lack the necessary specificity to address the practical issues and questions that arise in a commercial setting. Web scraping could be considered as a valid alternative strategy to acquire training data, but this comes with its own set of concerns and shortcomings.

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23 Amazon, for instance, offers a wide range of pre-build AI models and machine learning services, which can be used for business analytics, language processing, or text analytics. For more details, see the AWS Marketplace at https://aws.amazon.com/marketplace/solutions/machine-learning.

24 E.g., via Coursera or Udemy.

25 P. Louridas, *Algorithms* (Massachusetts: MIT Press, 2020), pp. 30–31.

26 *Ibid.*: '*We don't really care how long it takes to sort 10 items; after all, we can do that by hand. We care how long it takes to sort one million items or more. We want a measure of how we expect an algorithm to perform in problems that are not trivial.*'

27 See, for instance, the UCI Machine Learning Repository at https://archive.ics.uci.edu/ml/index.php. The repository offers datasets suitable for different training tasks (e.g., classification, regression, clustering, …), various data types (multivariate, univariate, sequential, time-series, …) and subject matters (life sciences, physics, business, …).

It follows from the digital nature of AI that the market for such systems remains fairly accessible and that entry barriers are not overly high. At the same time, it is plausible that achieving high market penetration will pose a more significant hurdle, notably due to data access limitations[28] and high hardware costs.

11. While the market for AI systems has some notable players anno 2023 – such as IBM[29], Microsoft[30], Google[31] and Amazon[32] –, the power dynamics on the market have not yet fully crystallised.[33] Yet, it is worth noting that the firms listed here feature a high level of vertical integration, implying that they are active on hardware, software, and service levels of the market. While this could pose potential problems in the future, there does not currently seem to be any clear evidence of anticompetitive behaviour in the market for AI systems. However, given the evolving nature of AI, competition authorities should be mindful of ongoing market trends. Market leaders obviously do not want to fall behind the curve and, thus, face strong incentives to continuously invest in AI-related technology. When such investments take on the form of mergers and acquisitions, this may impact the level of competition on the market.[34]

3. COMPETITION WITH AI – COMPETITIVE DYNAMICS VIA AI

3.1. CONCEPTUALISATION OF AI

12. Apart from creating an entirely novel market for AI systems, AI also affects *how* firms compete on the market. It is especially this dimension that attracts significant attention in scholarly literature.[35] When interacting with the existing

[28] This topic has been extensively covered in I. Graef, *EU Competition Law, Data Protection and Online Platforms: Data as Essential Facility* (Alphen aan den Rijn: Kluwer Law International, 2016), 418 p.

[29] See https://www.ibm.com/watson.

[30] See https://www.microsoft.com/en-us/ai.

[31] See https://ai.google/.

[32] See https://aws.amazon.com/ai/.

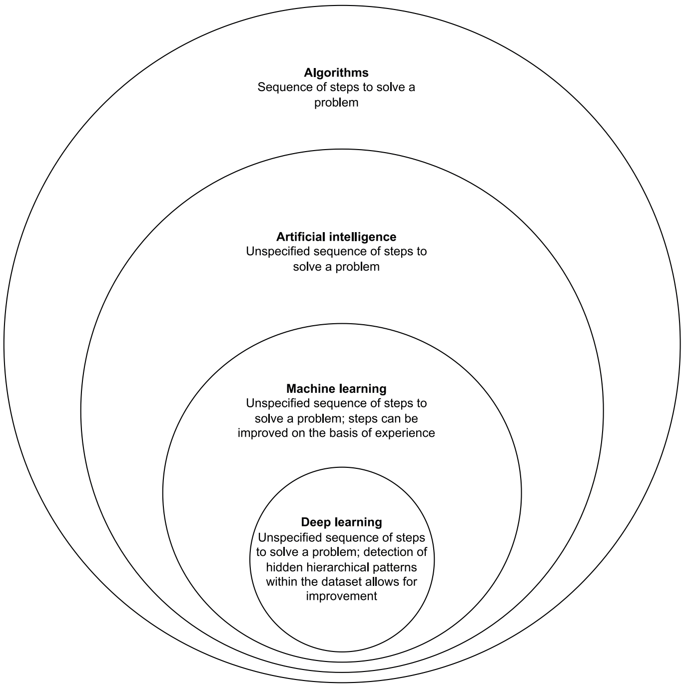
[33] J. Anderson, 'Do AI markets create competition policy concerns?', *Bruegel*, 2020, https://www.bruegel.org/2020/01/do-ai-markets-create-competition-policy-concerns/.

[34] See fn. 1; F. Beneke and M.-O. Mackenrodt, 'Remedies for algorithmic tacit collusion', *Journal of Antitrust Enforcement*, 2021, vol. 9, no. 1, p. 172.

[35] Notable contributions include: A. Ezrachi and M. Stucke, 'Artificial intelligence & collusion: When computers inhibit competition', *University of Illinois Law Review*, 2017, vol. 5, p. 1778; J. Harrington, 'Developing competition law for collusion by autonomous artificial agents', *Journal of Competition Law & Economics*, 2018, vol. 14, no. 3, pp. 331–333; N. Petit, 'Antitrust and Artificial Intelligence: A Research Agenda', *Journal of European Competition Law & Practice*, 2017, vol. 8, no. 6, p. 361; F. Beneke and M.-O. Mackenrodt, 'Artificial Intelligence

body of literature, it is useful to briefly reconsider a fundamental question: '*what is AI?*'. It should come as no surprise that numerous pages have been written on the meaning of notions such as machine-learning, artificial intelligence, and algorithms. While certainly meritorious, some important intricacies of AI have been overlooked and some misunderstandings made their appearance in legal scholarship.[36] For those reasons, a careful explanation of the functioning of AI will be provided first.

Figure 1. Visualisation of the relationship between algorithms, artificial intelligence, machine learning and deep learning.



3.1.1 Algorithms

13. At the outset, it should be noted that there is nothing particularly mysterious about an algorithm. For instance – and contrary to popular belief – algorithms have nothing to do with computers.[37] In fact, algorithms have existed long before computers made their appearance on the market. At its core, an

and Collusion', *IIC – International Review of Intellectual Property and Competition Law*, 2019, vol. 50, pp. 110–112.

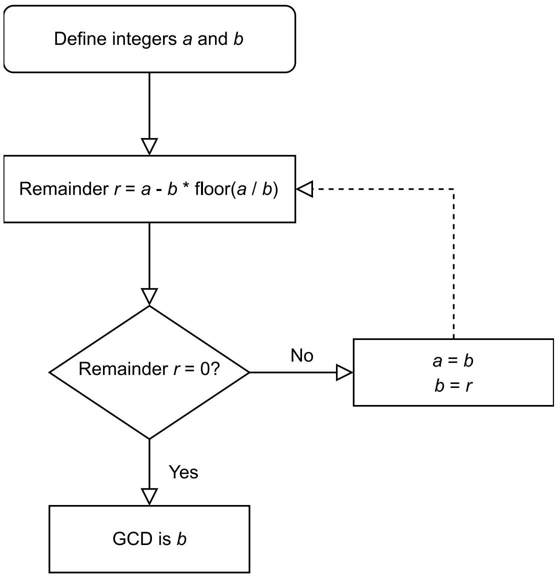
36 Also expressing this view is Petit, 'Antitrust and Artificial Intelligence: A Research Agenda', p. 361, who writes that '*AAI* [Antitrust and AI, ed.] *literature is the closest ever our field came to science-fiction*'.

37 Louridas, *Algorithms*, p. 4.

algorithm embodies nothing more than a set of clearly defined steps to solve a given problem.[38]

14. A good example of an algorithm is the methodology used to discover the greatest common divisor of two numbers, *a* and *b* (i.e., Euclid's algorithm).[39] As with other algorithms, Euclid's algorithm provides a series of sequential steps that involve specifying an input, doing basic calculations – such as additions, subtractions, divisions, and multiplications – on that input, and producing an output. It is useful to keep in mind that the outcome of one step can determine which second step to follow. Moreover, it happens that several steps are put in a *loop* and, in order to arrive at the correct output, it may be necessary to go through multiple *iterations* of that loop.

Figure 2. Visualisation of Euclid's algorithm via a flowchart diagram[40]



15. A crucial takeaway of any algorithm is that the steps of the algorithm can also be performed with pen and paper, thus confirming that there is nothing revolutionary about it.[41] What is novel, is that algorithms can presently be coded

[38] See, for instance, the definition provided by Webster's Dictionary: '*a set of steps that are followed in order to solve a mathematical problem or to complete a computer process*'; T. Cormen, C. Leiserson, R. Rivest et al., *Introduction to Algorithms*, 3rd edn (Massachusetts: MIT Press, 2009), pp. 5–6.

[39] A more in-depth explanation of this algorithm is provided in the Appendix (see 6.1 Euclid's algorithm).

[40] Louridas, *Algorithms*, p. i.

[41] Louridas, *Algorithms*, pp. 21–23.

in a computer programming language. Relying on a computer has the added benefit of parsing algorithms much quicker than any human being.[42] Yet, the steps performed by an encoded algorithm are the exact same steps as those performed using pen and paper.

3.1.2. Artificial Intelligence

16. According to its dictionary definition, AI is understood as '*an area of computer science that deals with giving machines the ability to seem like they have human intelligence*'.[43] Contrary to the algorithms mentioned above, the involvement of information technology is more apparent when assessing the functioning and performance of AI. The definition mentioned here seems to hint at AI's ability to somewhat act independently and to not require instructions prior to performing a computational step. However, 'seem' is an important operative word in this context. It would be inaccurate to state that AI possesses something that resembles human intelligence.[44] Conversely, it is better to hold that artificial intelligence involves algorithms of a more advanced nature; algorithms where some of the steps to be performed are not obvious at first sight. Whereas algorithms rely on a logic of ones and zeros, AI transcends this realm and introduces more complexity between one and zero.[45] Among others, it involves reasoning under uncertainty and introduces probabilistic reasoning.[46] Yet, as is the case for algorithms, the foundation of AI also hinges on taking a given input, performing a set of computational steps on that input, and producing the most optimal output that can occur within the boundaries of any predefined constraints.

3.2. UNPREDICTABILITY AND RANDOMNESS WITHIN AI SYSTEMS

3.2.1. Unpredictable AI Systems

17. AI is typically associated with an element of *unpredictability* or randomness. This unpredictability factor can easily materialize in very simple code snippets. Consider, for instance, the following:

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42 Thus, significantly reducing the computing time, which is one of the core constraints governing the usefulness of contemporary algorithms: T. Cormen, *Introduction to Algorithms*, pp. 11–12.

43 X, 'Artificial intelligence', *Webster's Dictionary*, 2021, https://www.merriam-webster.com/dictionary/artificial%20intelligence.

44 W. Ertel, *Introduction to Artificial Intelligence*, 2nd edn (London: Springer International, 2017), pp. 1–3: '*The attribute* artificial *might awaken much different associations. It brings up fears of intelligent cyborgs. It recalls images from science fiction novels*'.

45 Ertel, *Introduction to Artificial Intelligence*, pp. 9–10.

46 *Ibid*.

```
import random

possibilities = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
print(random.choice(possibilities))
```

18. The function mentioned here is tasked to pick a value from a list that includes all numbers between 1 and 10. As the code already suggests, there seems to be a degree of *randomness* attached to the selection of the number. When studying AI, some competition scholars refer to this unpredictable element of AI to argue that it is impossible to retrace the steps taken by the AI model (i.e., AI's black box).[47] The result is that literature sometimes instils an element of unpredictability on well-known algorithms or AI systems that in reality are more predictable than it may seem (for instance, due to the ability to retrace function calls or due to reverse engineering). Nonetheless, the unpredictable nature of AI is said to tie into notable competition law concerns such as different AI systems tacitly colluding with each other.[48] This triggers the question whether AI and competition law are on a collision course.

19. We are not to question the complexity of AI systems – be it because of the sheer amount of input data (i.e., big data systems) or because of the plurality in decision layers (e.g., the multitude of layers contained in random forests). However, we would like to take the opportunity to shed more light on the functioning of AI systems in order to argue that AI is, in fact, sometimes more predictable than one might think. The reality is that it is not entirely inconceivable to determine how an AI system arrives at a particular decision. Accordingly, while concerns surrounding the compatibility of AI and competition law are valid, the clash between both is occasionally exaggerated in literature.

20. We would like to support the thesis that there is no unpredictable AI, only rigidly trained AI and randomly trained AI.[49] Within this dichotomy,

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[47] F. Beneke and M.-O. Mackenrodt, 'Artificial Intelligence and Collusion', *IIC – International Review of Intellectual Property and Competition Law*, 2019, vol. 50, no. 1, p. 129; U. Schwalbe, 'Algorithms, Machine Learning, and Collusion', *Journal of Competition Law & Economics*, 2019, vol. 14, no. 4, p. 569; this discussion also regularly surfaces in a consumer context: T. Wischmeyer, 'Artificial Intelligence and Transparency: Opening the Black Box' in T. Wischmeyer and T. Rademacher (eds.), *Regulating Artificial Intelligence* (Cham: Springer, 2020), p. 76.

[48] Ezrachi and Stucke, 'Artificial intelligence & collusion: When computers inhibit competition', p. 1783; U. Schwalbe, 'Algorithms, Machine Learning, and Collusion', p. 575; G. Zheng and H. Wu, 'Collusive algorithms as mere tools, super-tools or legal persons', *Journal of Competition Law & Economics*, 2019, vol. 15, no. 2–3, p. 124; S. Thomas, 'Harmful signals: cartel prohibition and oligopoly theory in the age of machine learning', *Journal of Competition Law & Economics*, 2019, vol. 15, no. 2–3, pp. 159–160; B. Sørensen, 'Digitalisation: An Opportunity or a Risk?', *Journal of European Competition Law & Practice*, 2018, vol. 9, no. 6, p. 349.

[49] Also expressing this view, albeit without referring to it as such, is L. Eliot, 'Antitrust and Artificial Intelligence (AAI): Antitrust Vigilance Lifecycle and AI Legal Reasoning

rigidly trained AI systems are perceived as the typical expert systems, which are completely designed by humans. Their design stage usually revolves around linking a series of '*if…then…else…*'-statements and '*try…except…*'-statements and pairing those statements with several statistical functions. A fitting example are pricing algorithms: undertakings could rely on pricing algorithms to *algorithmically collude* with their competitors and implement price-fixing agreements through computer code.[50]

On the other hand, *randomly trained AI systems* refer to systems that can identify patterns within datasets, learn and improve of their own motion, without human intervention, prior classification or labelling of the available data. Customer segmentation models, aimed at creating personal shopping experiences, are a good example of this second category. The main risk here revolves around algorithmic collusion without any human facilitation, otherwise known as *algorithmic tacit collusion*.[51]

21. The statement that there is currently no 'unpredictable' AI might stir some controversy. However, since it underpins several of the findings of this contribution, some further clarification is needed prior to resuming the legal analysis. As shown above in the code snippet[52], the perceived unpredictability is the result of a specific step in AI's code. The assignment to pick a *random* number between 1 and 10, for instance, intuitively suggests that one value is indeed *randomly* chosen out of all available options. However, from a computer scientific point of view, this is not entirely correct.

22. AI does not perform choice steps on the basis of *true* randomness. In reality, choice steps are taken by relying on so-called randomness sources, usually provided by the computer that runs the AI model.[53] These randomness sources include, for instance, the current date and time (for simple use cases, e.g., random number generators) or mathematical functions (for complex use cases, e.g., cryptography).[54] A random choice step is thus determined through means of *pseudo*-randomness[55]: AI takes certain input data, AI relies on a well-known

Autonomy', *ArXiv*, 2020, https://arxiv.org/abs/2012.13016, p. 2: '*the AI can either be established in a means to be directed by human hands while undertaking antitrust behaviors, plus can be ostensibly let loose via the inclusion of Machine Learning and Deep Learning to perform antitrust behaviors without a human hand at the wheel per se*'; A. Deng, 'An Antitrust Lawyer's Guide to Machine Learning', *Antitrust*, 2018, vol. 32, no. 2, p. 82.

50 Deng, 'An Antitrust Lawyer's Guide to Machine Learning', p. 82.

51 *Ibid*.

52 See above at no. 17.

53 More information on these randomness sources can be found in the reference documentation of the Python Random library: X, 'Random – Generate pseudo-random numbers', *Python*, 2021, https://docs.python.org/3/library/random.html.

54 *Ibid*.; note that the reference documentation explicitly specifies not to use the (pseudo-) random generator for security purposes.

55 *Ibid*.

randomness source, and AI outputs a pseudo-random result. The result is that even complex AI systems can yield deterministic outputs once the randomness source has been identified.

3.2.2. Random Seed Values

23. In scientific research communities, the findings of any study need to be reproducible. This implies that, when a study is repeated, the same results should be found. The same reasoning holds true for AI systems. Reliability-wise, it is good practice to pursue reproducibility when working with AI systems. To that end, AI systems have the ability to adhere to a reproducibility requirement.[56] In practice, this entails that the randomness source is predefined by the user rather than relying on the system time and date. A manually specified randomness source is called the 'seed'. A use case is provided below:

```
1  import random
2
3  possibilities = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
4  random.seed(13)
5  print(random.choice(possibilities))
```

24. Contrary to the example in no. 17, the code snippet here will consistently yield the same number. Technically speaking however, this number is still chosen in a random manner. However, by specifying the seed value in line 4, it is possible to ensure that the code snippet always uses the same randomness, therefore leading to reproducibility.

3.2.3. Choice Layers, Iterations and Input Value Combinations

25. When using large datasets, it is highly plausible that several choice steps need to occur within the training stage of the AI system. An optimisation AI affords us a good example of this phenomenon and its implications.

Suppose we have the following array of numbers: [1, 2, 3, 4, 5]. Imagine if we now were to task AI to consecutively pick two (unique) numbers and to optimise the sum of these two numbers to approach the value 10. In the first step, the system must choose (pseudo-)randomly between 1 and 5. Assume that the firstchoice step yields the number 2. During the secondchoice step, the system needs to pick from the remaining numbers [1, 3, 4, 5]. This is illustrated below:

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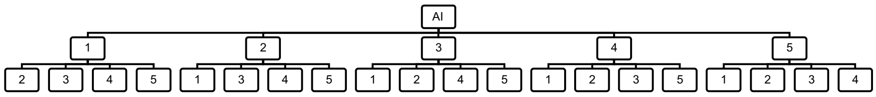
56 *Ibid.*: '*Sometimes it is useful to be able to reproduce the sequences given by a pseudo-random number generator. By re-using a seed value, the same sequence should be reproducible from run to run […]*'.

Figure 3. Overview of two sequential random choice steps



26. A first iteration of the program could result in the combination 2 + 4 = 6. This outcome corresponds to an error value of 10 – 6 = 4. If we were to run the program for a second iteration, it could pick 4 + 3 = 7 and yield an error value of 10 – 7 = 3. It now becomes obvious that this particular system has two layers of choice steps. In order to have a fully trained AI model, which can optimise for the value 10, many iterations through these two layers will be necessary. If the number of iterations is high enough, the optimised output will either be 4 + 5 or 5 + 4. Both combinations have the lowest possible error value of 10 – 9 = 1.

27. The explanation from the previous paragraph describes how any AI model works: optimisation occurs by continuously looping through the different options within the various choice steps until the returned error value is as small as possible. If we apply this reasoning to the abovementioned *rigidly trained AI systems*[57], the choice steps are explicitly integrated in the programme's code. The implication thereof is that the outcome will always squarely fall within the possibilities the programmer had anticipated. For instance, an AI model could produce a signal indicating that an undertaking should lower its product prices after having assessed the price levels of competing firms.

Matters are a bit more complicated for *randomly trained AI systems*[58] since the choice steps are not pre-programmed. Although this gives the appearance of randomness, there are only a finite amount of input variable combinations the AI model can turn into choice steps. It will most certainly require effort to determine where the output value will land, and which parameters will have contributed the most to this output. Nonetheless, this is not an absolute impossibility.

An added detail here is the ability of more complex AI systems to improve and learn from experience. When applied, this could be reflected in the AI model no longer choosing number 1 during any of the choice steps after several iterations because, after a while, the model has 'figured out' that picking number 1 consistently yields larger error values when compared to selecting any of the other four numbers.

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57 See above at no. 20.
58 See above at no. 20.

3.2.4. About Pebbles and Bouncy Balls

28. If we resort to a metaphorical approach, rigidly trained AI systems can best be compared to *pebbles*: once a pebble is dropped, it will remain still once it has touched the ground. Randomly trained AI systems rather fit the description of *bouncy balls*: once a bouncy ball is dropped, it will keep bouncing around for a while before eventually remaining still on the ground. In both types of AI systems, the area wherein the dropped pebble or bouncy ball can eventually be found, is demarcated.

This is obvious for pebble systems as they can, by definition, not make any decision the creator has not planned for. At the same time, this also holds true for bouncy systems, given that these systems are also leveraging the know-how of its creator. The difference is that for bouncy systems, the creator's relevant know-how does not cover all possible input value combinations, whereas this is the case for pebble systems.

29. In the example from no. 25, where we optimised the sum of two integers to approach 10, it is not useful to know all possible combinations the AI system can make in an attempt to produce the output value with the lowest error. It is only required to have prior knowledge of the possible inputs and to understand the basic principles of the field. Even if 'all possible inputs' includes an enormous number of irrelevant parameters and AI must find the gold nuggets – which is exactly how big data algorithms work – these general principles will apply.

30. Throughout the remainder of this chapter, it is useful to keep in mind that humans can scrutinise the input values AI might use and evaluate how the basic principles of AI take effect. Once choice steps can be identified, it also becomes possible to make projections and estimations about the model's functioning. Understandably, it will take valuable time to fully grasp the intricacies of real-world AI models; time which may need to be committed elsewhere. Nevertheless, recent decisions taken by the European Commission (EC) and judgments rendered by the Court of Justice (CJEU) indicate that technical discussions occasionally come to the forefront as well.[59]

Building further on this, it is a worthwhile effort for undertakings and competition authorities alike to reflect on the functioning of AI models when necessary, in an effort to get a better understanding of what AI does and what it does not do. As shown, seemingly unpredictable outcomes should not be a genuine factor that discourages these efforts. Although an AI model's complexity

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59 See, for instance, Commission Decision of 3 September 2014, Case AT.39574, *Smart Card Chips* and the ensuing discussions during the appellate proceedings on whether SIM card chips and non-SIM card chips are part of the same market in CJEU 15 December 2016, no. T-758/14, ECLI:EU:T:2016:737, *Infineon Technologies v Commission*.

is an important factor as well, it should be borne in mind that it is always possible to uncover the model's functioning, sometimes by literally (re)tracing the model's underlying function calls.

3.3. IMPLICATIONS OF DECISION-MAKING BY AI FOR COMPETITION LAW

3.3.1. How AI Changes Commercial Decision-Making

31. The chapter now turns to the reasons why AI has become such an important tool in steering a firm's commercial decision-making on the market. What algorithmic *loops* and *iterations* are doing, is testing all possible combinations of input variables until the best – or near best – decision is found. The goal of this decision could be anything, ranging from a marketing firm looking to devise a slogan that will attract the most attention (by applying regression models to the performance metrics acquired from previous slogans) to a law boutique attempting to identify the relevant legislation needed to best advise their clients (by resorting to text mining and building a classification tree). In essence, if tasks are of a repetitive nature and if output values can be captured in predeterminable options, it is plausible that those tasks can be fully automated.

32. The topic of the automation and the future of commerce has been repeatedly covered in both scholarly[60] and popular[61] literature. The competition law implications of automation have not been overlooked either.[62] While firms have used algorithms in the past and will continue to do so in the future, it is especially the sheer amount of computing power available to undertakings which regularly thrusts AI into the limelight nowadays. The increased computational capabilities in a commercial context tie into lower entry barriers to work with algorithms and AI systems.[63] When considering the relevant AI legal scholarship on the topic, the focus lies, on the one hand, on plausible risks[64] created by contemporary AI systems and, on the other hand, on potential or

60 E.g., W. Wang and K. Siau, 'Artificial Intelligence, Machine Learning, Automation, Robotics, Future of Work and Future of Humanity: A Review and Research Agenda', *Journal of Database Management*, 2019, vol. 30, no. 1, pp. 61–79; J. Wajcman, 'Automation: is it really different this time?', *British Journal of Sociology*, 2017, vol. 68, no. 1, pp. 119–127.

61 E.g., X. 'Free exchange: It's a bot time', *The Economist*, 2021, vol. 438, no. 9228, p. 70.

62 Ezrachi and Stucke, 'Artificial intelligence & collusion: When computers inhibit competition', p. 1778; Eliot, 'Antitrust and Artificial Intelligence (AAI): Antitrust Vigilance Lifecycle and AI Legal Reasoning Autonomy', pp. 6–8.

63 See above at no. 10.

64 A. Ezrachi and M. Stucke, *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy* (Cumberland: Harvard University Press, 2016), pp. 35–36.

theoretical risks[65] created by AI systems that are on the horizon.[66] The literature is unanimous in at least one respect though: algorithmic competition is on the rise. And with algorithmic competition comes the risk of impeding effective competition.

3.3.2. Article 101 TFEU and the Risk of Concerted Practices via AI

33. It is accepted knowledge that cartelisation is harmful to the market. Cartel agreements or concerted practices between undertakings are known for generating strong anticompetitive effects, such as increasing prices above competitive levels and decreasing production volumes. In these instances, consumers are confronted with a situation where they either have to choose not to purchase a particular product or to pay an above-market price for that product. As a result, cartelised products have the effect of transferring wealth from the hands of the consumer into the hands of the cartel members. Additionally, entering into cartel agreements also shields the individual cartel members from the competitive pressure of the market, which under normal circumstances would incite these undertakings to keep innovating to remain effective. For those reasons, cartelisation – whether tacit or not – is caught under Article 101 TFEU.[67]

A. Algorithmic (Tacit) Collusion

34. Many cartel agreements concern either price fixing arrangements or output restrictions between direct (horizontal) competitors active in the same market. Given that the price is an essential element of any product, it should come as no surprise that pricing algorithms and production planning algorithms are well integrated in (online) markets and that they have also been the subject of scholarly research in the past.[68] The underlying principle of these algorithms is that a firm should take both their own production costs and their competitors' prices into consideration when setting a price.[69] When the relevant

65 Beneke and Mackenrodt, 'Remedies for algorithmic tacit collusion', p. 155; A. von Bonin and S. Malhi, 'The Use of Artificial Intelligence in the Future of Competition Law Enforcement', *Journal of European Competition Law & Practice*, 2020, vol. 11, no. 8, p. 469.

66 Beneke and Mackenrodt, 'Artificial Intelligence and Collusion', p. 125 capture this discussion quite well under the heading '*What, if Anything, Changes with AI?*'.

67 See the references above at fn. 9.

68 E. Calvano et al., 'Artificial Intelligence, Algorithmic Pricing, and Collusion', *American Economic Review*, 2020, vol. 110, no. 10, p. 3268; Schwalbe, 'Algorithms, Machine Learning, and Collusion', p. 568; Harrington, 'Developing competition law for collusion by autonomous artificial agents', p. 331; Ezrachi and Stucke, 'Artificial intelligence & collusion: When computers inhibit competition', p. 1777; Beneke and Mackenrodt, 'Remedies for algorithmic tacit collusion', p. 164.

69 G. Delporte, *Pricing algorithms in EU competition law* (Apeldoorn: Maklu Publishers, 2019), p. 19, para. 21.

inputs are determinable (e.g., what are the prices of my competitor's products?) and the output is a single number (e.g., what would be my optimal price?), these calculations can be performed by means of computer code.[70]

35. Amazon affords us a rather amusing example of pricing algorithms.[71] In 2011, a researcher at UC Berkeley was looking to purchase an academic textbook. Great was his astonishment when discovering that new copies of the textbook were listed at prices starting from $1,730,045.91 (+ $3.99 shipping), whereas used copies would cost only $35.54. A brief investigation soon followed, which revealed that two vendors of new textbook copies relied on algorithmic pricing.[72] Each day, vendor X would automatically adjust the book's price by a factor 0.9983 on the basis of the price charged by vendor Y. At the same time, vendor Y would also alter its price on a daily basis with a factor 1.270589 by looking at the price charged by vendor X. This pattern continued for some time, with outrageous prices as a result.

36. In competition law literature, the use of pricing algorithms has mostly been studied under Article 101 TFEU.[73] Notable literature on this topic includes the seminal work titled '*Virtual Competition*' by Ezrachi and Stucke.[74] The book covers several thought-provoking topics such as collusion and behavioural discrimination. One of their main theses revolves around algorithmic tacit collusion, a phenomenon where the interactions between algorithms owned by different competitors will likely generate anticompetitive effects without the need for an explicit cartel agreement.[75] According to the authors, such instances are likely to occur in concentrated markets that are typified by fairly homogenous products (e.g., fruits, chemicals, or metals).[76] These characteristics prove ideal for algorithms to monitor changes in the market and adjust product prices accordingly once deviations (e.g., discounts) are detected.

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70 A. Capobianco, Algorithms and Collusion – Note from the European Union', *OECD*, 2017, https://one.oecd.org/document/DAF/COMP/WD(2017)12/en/pdf, p. 3, para. 9: '*[O]nline prices are highly transparent. Monitoring can be done at short time intervals and at a low cost. Firms can use software to automatically monitor competitors' prices almost in real time, and adapt prices (or "reprice") accordingly*'.

71 M. Eisen, 'Amazon's $23,698,655.93 book about flies', *Michael Eisen*, 2011, https://www.michaeleisen.org/blog/?p=358; Ezrachi and Stucke, *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy*, p. 13.

72 *Ibid*.

73 See the references above at fn. 67.

74 A. Ezrachi and M. Stucke, *Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy* (Cumberland: Harvard University Press, 2016), 365 p.

75 *Ibid*., p. 56 ff.

76 *Ibid*., p. 60; A. Ezrachi and M. Stucke, 'Algorithmic Collusion: Problems and Counter-Measures', *OECD*, 2017, https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DAF/COMP/WD%282017%2925&docLanguage=En, p. 3, para. 8.

37. Combining views from the available literature suggests that at least three scenarios pertaining to algorithmic collusion are worth reflecting upon[77]:

a. *AI to facilitate explicit coordination*. A first scenario, which clearly falls within the ambit of Article 101 TFEU, is the use of algorithms to explicitly facilitate cartelisation. At the time of writing, several notable decisions are available on this topic. In both *CMA v. Trod and GBE*[78] and *US v. Topkins*[79], conspirator-undertakings agreed to design and adopt price-fixing algorithms with the specific intention to fix, increase, maintain, and stabilise prices, respectively in the market for sports and entertainment merchandise and in the market for posters and wall decoration. In 2018, the EC also fined four consumer electronics manufacturers for engaging in resale price maintenance (RPM) through means of price monitoring and price adjustment software.[80] Retailers that were found to be selling products below a certain price level, were explicitly asked by manufacturers to increase their prices.
b. *AI as a hub-and-spoke arrangement*. A second scenario involves instances where price recommendations or price setting happens through means of an AI system controlled by an intermediary party.[81] Bringing a third-party into the equation may facilitate a hub-and-spoke arrangement that eventually results in above-market prices. Situations susceptible to such AI-based hub-and-spoke dynamics may, for instance, implicate sellers that rely on automatic pricing tools offered by websites such as Amazon, eBay, Uber or Airbnb.[82] Anno 2023, the usage of AI in a hub-and-spoke setting has received some coverage by national competition authorities, but there is presently no case law available on this topic.[83]

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77 Competition & Markets Authority, 'Algorithms: How they can reduce competition and harm consumers', *CMA*, 2021, https://www.gov.uk/government/publications/algorithms-how-they-can-reduce-competition-and-harm-consumers/algorithms-how-they-can-reduce-competition-and-harm-consumers.

78 CMA 12 August 2016, Case no. 50223, *CMA v. Trod and GBE*.

79 US District Court ND California 21 October 2015, no. CR 15–00201 WHO, *US v. Topkins*; see also S. Mehra, 'US v. Topkins: can price fixing be based on algorithms?', *Journal of European Competition Law & Practice*, 2016, vol. 7, no. 7, p. 471.

80 Commission Decision 24 July 2018, Case AT.40465, *Asus,* para. 27; Commission Decision 24 July 2018, Case AT.40469, *Denon & Marantz,* para. 95; Commission Decision 24 July 2018, Case AT.40181, *Philips*, para 64; Commission Decision 24 July 2018, Case AT.40182, *Pioneer*, paras. 136 and 155.

81 Ezrachi and Stucke, *Virtual Competition*, p. 47; Competition & Markets Authority, 'Pricing algorithms', *CMA*, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746353/Algorithms_econ_report.pdf, pp. 26–27.

82 Competition & Markets Authority, 'Algorithms: How they can reduce competition and harm consumers', *CMA*, 2021, https://www.gov.uk/government/publications/algorithms-how-they-can-reduce-competition-and-harm-consumers/algorithms-how-they-can-reduce-competition-and-harm-consumers.

83 S. Li, C. Chunying Xie and E. Feyler, 'Algorithms & Antitrust: an overview of EU and national case law', *Concurrences Antitrust Publications & Events*, 2021, https://www.concurrences.

c. *AI to facilitate tacit collusion*. A third and final scenario concerns complex algorithms that can learn and improve on their own and that may engage in autonomous tacit collusion.[84] Stated otherwise, in theory, when using advanced AI models, collusion can occur without explicit communication between undertakings or collusive intentions by their human AI designers. While theories on algorithmic tacit collusion have contributed to an extensive body of literature, it must be noted that no cases involving AI and tacit collusion have been brought yet.

38. The categorisation of algorithmic collusion in three different types offers a refreshing perspective. While scenarios involving explicit coordination and hub-and-spoke dynamics are plausible, literature seems divided as to whether the third type of algorithmic collusion – tacitly colluding price algorithms – is purely theoretical or not.[85] It is accepted that if competitors have fairly homogenous products, then competitors' prices will be more transparent to all market participants and collusion is more likely to occur.[86] However, some scholars argue that this type of 'accidental' collusion – by means of using similar software or similar software settings – does not fall under the cartel prohibition.[87] Another strand of literature refers to the lack of empirical evidence in support of the algorithmic tacit collusion rationale, the rather reductive assumptions about market conditions, or the simplified understanding of price algorithms' operational environment.[88]

39. According to the authors, assessing tacitly colluding algorithms under Article 101 TFEU poses serious challenges. On the one hand, if algorithms respond to each other's (public) signals, there is an argument to be made that

com/en/bulletin/special-issues/algorithms-antitrust-en/general-antitrust-3924/algorithms-antitrust-an-overview-of-eu-and-national-case-law.

84 Ezrachi and Stucke, *Virtual Competition*, p. 56.

85 T. McSweeny, 'Algorithms and Coordinated Effects', *University of Oxford Center for Competition Law and Policy*, 2017, https://www.ftc.gov/system/files/documents/public_statements/1220673/mcsweeny_-_oxford_cclp_remarks_-_algorithms_and_coordinated_effects_5–22–17.pdf, p. 3; G. Delporte, *Pricing algorithms in EU competition law*, p. 37, para. 53; Competition & Markets Authority, 'Algorithms: How they can reduce competition and harm consumers', *CMA*, 2021, https://www.gov.uk/government/publications/algorithms-how-they-can-reduce-competition-and-harm-consumers/algorithms-how-they-can-reduce-competition-and-harm-consumers.

86 Germany's Monopolies Commission, 'Algorithms and collusion', *Monopolkommission*, 2018, https://www.monopolkommission.de/images/HG22/Main_Report_XXII_Algorithms_and_Collusion.pdf, pp. 6–7, paras. 179–181.

87 Schwalbe, 'Algorithms, Machine Learning, and Collusion', p. 597; Beneke and Mackenrodt, 'Remedies for algorithmic tacit collusion', p. 153.

88 A. Deng, 'When Machines Learn to Collude: Lessons from a Recent Research Study on Artificial Intelligence', *SSRN Scholarly Papers*, 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3029662, p. 1 and pp. 4–5.

tacitly concerted practices are – or could be – happening. This is especially true when algorithms use similar inputs or share commercially sensitive information.

On the other hand, it must be recalled that a high standard of proof applies to the finding of a concerted practice.[89] A close reading of the relevant CJEU case law indicates that a concerted practice involves an element of coordination between undertakings, which cannot be attributable to an agreement or decision, but which is nevertheless caught under Article 101 TFEU.[90] *Dyestuffs*[91] and *Suiker Unie*[92] suggest that the legal test for the finding of a concerted practice revolves around a mental consensus between undertakings – through either direct or indirect contact – where competition is knowingly substituted by cooperation.[93]

40. Especially the criteria of 'mental consensus' and 'knowingly substituting competition' create a significant hurdle for the qualification of AI-driven conduct as a concerted practice. While it may be possible to predict which commercial strategy market rivals might pursue and while these same market rivals may also accurately predict your commercial strategy, the doctrine on *intelligent adaptation*[94] from *Suiker Unie* could offer a valid argument against such qualification: in principle, firms are entitled to intelligently adapt their market strategy to the conduct of their competitors.[95]

For pricing algorithms in particular, the core argument holds that firms signal their intentions via openly communicated prices, which AI models can subsequently pick up. For the most part, these data ripples are created

89 M. Gassler, *Information Exchange Between Competitors in EU Competition Law* (Alphen aan den Rijn: Kluwer Law International, 2021), p. 127.

90 CJEU 14 July 1972, no. C-48/69, ECLI:EU:C:1972:70, *ICI v Commission (Dyestuffs)*; CJEU 16 December 1975, no. C-40/73 etc., ECLI:EU:C:1975:174, *Suiker Unie v Commission (Sugar Cartel).*

91 CJEU 14 July 1972, no. C-48/69, ECLI:EU:C:1972:70, *ICI v Commission (Dyestuffs)*, para. 66: '*[Article 101 TFEU] draws a distinction between the concept of "concerted practices" and that of "agreements between undertakings" or of "decisions by associations of undertakings"; the object is to bring within the prohibition of that article a form of coordination between undertakings which, without having reached the stage where an agreement properly so-called has been concluded, knowingly substitutes practical cooperation between them for the risks of competition*'.

92 CJEU 16 December 1975, no. C-40/73 etc., ECLI:EU:C:1975:174, *Suiker Unie v Commission (Sugar Cartel)*, para. 174: '*[The] requirement of independence does not deprive economic operators of the right to adapt themselves intelligently to the existing and anticipated conduct of their competitors, it does however strictly preclude any direct or indirect contact between such operators, the object or effect whereof is either to influence the conduct on the market of an actual or potential competitor or to disclose to such a competitor the course of conduct which they themselves have decided to adopt or contemplate adopting on the market*'.

93 Whish and Bailey, *Competition Law*, p. 118.

94 CJEU 16 December 1975, no. C-40/73 etc., ECLI:EU:C:1975:174, *Suiker Unie v Commission (Sugar Cartel)*, para. 174.

95 OECD, 'Unilateral disclosure of information with anticompetitive effects', *OECD Working Paper DAF/COMP/WP3(2012)1*, 2012, p. 18.

unintentionally in the normal course of business. For the AI model, acting on the basis of these signals is sufficient to create a mutual understanding between competitors. Further to this, in line with the wording of the Guidelines on Horizontal Cooperation Agreements, such conduct also has strong potential to 'reduce strategic uncertainty' in the market, which is a key element in the assessment of a concerted practice.[96] However, for the company executives, it could be the case that no mental consensus was reached nor that an intentional substitution of competition took place. Therefore, if strictly adhered to the current case law principles, the technological capabilities of AI suggest that algorithmic tacit collusion can occur, but that such conduct may escape the ambit of Article 101 TFEU due to a lack of mental consensus among competitors.

41. Another point of interest also deserves attention, namely the fact that, for concentrated industries in specific, several other conditions must be met in order to prove a concerted practice.[97] These conditions tie into the *oligopoly defence*[98]: in concentrated markets, the theory of oligopolistic interdependence asserts that a certain degree of parallel conduct between competitors is to be expected, given that the possession of extensive market power naturally incites competitor-firms to match each other's conduct.[99] Hence, pursuant to *Airtours*[100], competition authorities can only qualify conduct as tacit coordination when three conditions are met[101]:

(i) Transparency: 'each member of the dominant oligopoly must have the ability to know how the other members are behaving in order to monitor whether or not they are adopting the common policy'.[102]
(ii) Sustainability: 'there must be an incentive not to depart from the common policy on the market'.[103]
(iii) Absence of competitive restraints: 'the foreseeable reaction of current and future competitors, as well as of consumers, would not jeopardise the results expected from the common policy'.[104]

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96 Communication from the Commission – Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements [2011] OJ C 11/1, paras. 60–63.
97 C. Veljanovski, 'Algorithmic Antitrust: A Critical Overview' in A. Portuese (ed.), *Algorithmic Antitrust* (Cham: Springer, 2022), p. 56.
98 N. Petit, 'The oligopoly problem in EU competition law' in I. Lianos and D. Geradin (eds.), *Handbook on European Competition Law. Substantive Aspects* (Cheltenham: Edward Elgar Publishing, 2013), pp. 289–290.
99 M. Gassler, *Information Exchange Between Competitors in EU Competition Law*, p. 127; R. Posner, *Antitrust Law* (Chicago: University of Chicago Press, 2001), pp. 55–56.
100 CJEU 6 June 2002, no. T-342/99, ECLI:EU:T:2002:146, *Airtours*.
101 Whish and Bailey, *Competition Law*, p. 598.
102 CJEU 6 June 2002, no. T-342/99, ECLI:EU:T:2002:146, *Airtours*, para. 62.
103 *Ibid*.
104 *Ibid*.

As a result, while it is true that AI systems could dispense with human interactions between competitors, it must be prevented that concerted practices become conflated with objective business decisions and conscious parallelism.[105] Consequently, tacit oligopolistic collusion hinges on a set of specific structural and behavioural market conditions.[106] In an oligopolistic setting, the threat of algorithmic tacit collusion must therefore not only consider the technical challenges surrounding the assessment of self-learning and autonomously coordinating algorithms, but also the market-specific circumstances.

42. On balance, it is difficult to make definitive statements on how to handle complex AI models from a competition law point of view. In theory, algorithmic tacit collusion could circumvent Article 101 TFEU given the absence of direct contact or a meeting of minds among competitors. Furthermore, undertakings could invoke the oligopoly defence and plausibly argue that parallel conduct is a natural occurrence when markets are relatively concentrated.

At first sight, this suggests that a gap in the EU rules on cartels exists and that AI systems may provide entrepreneurs with an opportunity to obscure anticompetitive conduct behind the opaqueness of their algorithmic models. Yet, it could also be argued that EU competition law is flexible enough to deal with these instances. As recalled, the conditions apropos mental consensus and the threefold test originating from *Airtours* are not enshrined in the Treaty. Consequently, nothing prevents Europe's highest court from overturning or refining existing case law when the need to do so arises.

Moreover, it must be emphasised again that there is no clear empirical evidence to corroborate the phenomenon of algorithmic tacit collusion. While some computer simulations indicate that tacit collusion between AI systems is theoretically possible[107], real world evidence is lacking.[108] Nonetheless, this does not detract from the fact that the use of complex AI models triggers interesting questions for competition enforcement authorities and that further research into suitable remedies is recommended.

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105 N. Petit, 'The oligopoly problem in EU competition law', p. 290.

106 C. Veljanovski, 'Algorithmic Antitrust: A Critical Overview', p. 56.

107 T. Klein, 'Autonomous algorithmic collusion: Q-learning under sequential pricing', *The RAND Journal of Economics*, 2021, p. 540: '*[The] main finding is that when the number of discrete prices is limited, competing Q-learning algorithms indeed often coordinate on collusive equilibria. The intuition behind this outcome is that Q-learning first learns the short-run benefit of slightly undercutting its competitor, but then also learns through experimentation the longer-run benefit of "resetting" this gradual price decline with a large price increase once prices become low*'; E. Calvano et al. 'Artificial Intelligence, algorithmic pricing and collusion', *SSRN Scholarly Papers*, 2019, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3304991, p. 3: '*The results indicate that, indeed, relatively simple pricing algorithms systematically learn to play collusive strategies. The algorithms typically coordinate on prices that are somewhat below the monopoly level but substantially above the static Bertrand equilibrium*'.

108 C. Veljanovski, 'Algorithmic Antitrust: A Critical Overview', p. 55.

B. Removing Information Asymmetries via AI

43. A topic that has received less attention is AI's ability to remove any information asymmetry between firms, not just pricing. Literature suggests that cartels, by definition, are unstable given that each individual cartelist has an incentive to cheat on the other firms involved in the cartel.[109] These dynamics are often compared to a prisoner's dilemma, where all firms eventually end up trying to deceive each other.[110] Yet, this principle only holds true when the individual participants are unaware of each other's moves. This could also provide an explanation as to why cartel decisions often refer to the exchange of commercially sensitive information to corroborate the existence of a cartel.

44. From a cartelist's point of view, managers will likely remain reluctant to commit to a cartel without the exchange of sensitive documents. The effects thereof are twofold. On the one hand, by mutually exchanging sensitive information between cartelists, one firm gains leverage over the other and vice versa, thus generating deterrence effects that somewhat resemble the threat of mutually assured destruction. On the other hand, the exchange of documents takes away any information asymmetry and facilitates the preservation of the cartel.

A similar conclusion can be drawn from an enforcement angle. The EC mostly refers to specific emails[111], employee schedules[112], or internal memos[113] when looking to find and subsequently dismantle cartels. Based on this reasoning – and without having experience running a cartel – we are willing to speculate that these documents are inculpatory precisely because they are aimed at removing information asymmetries around the cartelised object or because they serve to verify or uphold the intentions of the other cartelists.

45. These observations tie into two crucial findings. Firstly, if there are no information gaps between firms – be it vis-à-vis price, quantity, research, or firm expansions – there is no longer a need to 'create evidence' of the cartel by means of exchanging inculpatory documents. Secondly, if there is no need to exchange sensitive information, it also follows that there is no need to check the good faith behaviour of the other cartelists (within the cartel, that is). On balance,

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109 Ezrachi and Stucke, *Virtual Competition*, p. 35; M. Levenstein and V. Suslow, 'What Determines Cartel Success?', *Journal of Economic Literature*, 2006, vol. 44, no. 1, p. 44.

110 Schwalbe, 'Algorithms, Machine Learning, and Collusion', p. 581; Beneke and Mackenrodt, 'Artificial Intelligence and Collusion', pp. 114–117; A. Deng, 'When Machines Learn to Collude: Lessons from a Recent Research Study on Artificial Intelligence', *SSRN Scholarly Papers*, 2017, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3029662, p. 3.

111 CJEU 9 September 2019, no. T-84/13, ECLI:EU:T:2015:611, *Samsung SDI and Others v Commission*, para. 69.

112 CJEU 3 September 2009, nos. C-332/07 P, C-327/07 and C-338/07 P, ECLI:EU:C:2009:500, *Papierfabrik August Koehler and Others v Commission*, para. 62.

113 CJEU 16 June 2011, no. T-240/07, ECLI:EU:T:2011:284, *Heineken Nederland and Heineken v Commission*, para. 119.

by removing information asymmetries, AI can facilitate cartelisation without leaving any trace – or at least by making evidence of cartelisation scarce. In turn, this could considerably complicate competition authorities' objective to dislodge cartels.

46. It is worthwhile to consider the overall picture at this point. Firms generate *ripples of information*, which can be picked up by AI systems, regardless of whether these firms have a desire to do so or not. At the extreme, it is conceivable that AI systems can uncover enough ripples – both obvious and non-obvious ones – to allow a firm to find out what its competitor is doing. In other words, the more complex AI systems become, the more difficult it will be to keep information asymmetries in place to facilitate effective competition. As such, complex AI systems provide a means to tacitly collude in a way not thought possible at the time of the drafting of Article 101 TFEU.

47. The configuration and performance of an AI model hinges on two factors: feeding it all possible options for a choice step and providing it with a definition of success. When these prerequisites are met, AI will eventually be able to anticipate some future ripples as well. In high-performance AI models, at least some predictions are likely to classify as 'statistically significant', suggesting that predicted ripples will correspond to the real-world ripples with a certain degree of certainty.[114] Whereas descriptive analytics (i.e., what has happened in the past?) are oftentimes said to belong to the realm of pure statistics, AI goes one step further by facilitating predictive analytics (i.e., what will happen in the future?) and prescriptive analytics (i.e., how to affect future outcomes?).

48. It is not far-fetched to say that competitor firms will also rely on the same – or at least similar – algorithms to determine their best course of action. Thus, a firm's competitors will also attempt to move towards its optimal production configuration and make estimations about other market actors' optimal performance levels. Therefore, in homogenous markets where players possess similar know-how and have a similar understanding of the technical possibilities and limitations of a production process, each individual firm can deduce what competitor firms might do in terms of their behaviour on the market.

C. Exploring the Market for Grenadine – A Code Example

49. It is useful to consider a specific code example to illustrate how these findings play out in real-life and to touch on some of the inner workings of AI systems. These findings also serve the purpose of confirming that the removal of

[114] The 'error' or 'definition of success' can be anything; it does not need to be a numerical value, but can also be the occurrence of certain facts (e.g., the registration of IP).

information asymmetries via AI is no longer science fiction. Readers can find the annotated pseudo-code of our example in the Appendix.[115]

50. A first step in designing an AI system is establishing what the algorithm should yield as an outcome. For instance, a CEO might be wondering 'will my competitor lower its product prices?', 'has my competitor access to technology that I am unaware of?' or 'is my competitor going to change production methods?'.

A second step revolves around the identification of the events or instances that can or need to happen to trigger a change in competitors' conduct. Especially this second step illustrates that prior, intimate knowledge of the field is crucial for the proper functioning of the AI model.[116] For instance, the second step can be implemented more accurately when the CEO is familiar with the different aspects of the production chain, has an in-depth understanding of the tools and machinery, and has the ability to identify where interruptions in the production process could occur.

51. Detail is important in computer models, which is why the example needs to be more specific as well. For this illustration, we will explore the market for grenadine by tailoring the AI model to a grenadine production corporation. Our AI model, while containing some simplified functions, is fully capable of answering the CEO's three questions from the previous paragraph. However, the reader should keep several limitations of the model in mind. Firstly, the model assumes that the CEO is running his grenadine making operation in a limited market, as applying the model to open market conditions would require several significant modifications. Secondly, the AI model only assesses price competition against what the current ideal price could be, considering the currently available know-how and desired profit targets. Thirdly, all things considered, the model remains a model, which means that the control variable 'price' remains a simplification when compared to a real-world price for grenadine.

52. The AI system calculates the best possible price given a structured array of options (pertaining, for instance, to the production steps or raw inputs).[117] Immediately, the question 'does my competitor know something I don't' can be answered:

a. When the competitor's price is lower than the optimal grenadine price calculated by the AI system, it follows that the competitor knows something the CEO doesn't. More concretely, this ties into situations where, for instance, the competitor has access to cheaper production inputs or where he relies on a more efficient production process. After all, the CEO provided all

115 See below at no. 93.
116 In no. 29, we referred to these informational aspects as 'the basic principles of the field'.
117 See the code example in the Appendix.

information to the model what he thought possible for his competitor as well as the know-how pertaining to his own production process.

b. When the prices set by the competitor lie far below what the model considers possible – while taking a reasonable margin of error into account –, the only possible conclusion is that the competitor is (anticompetitively) selling at a loss.

While the grenadine market model is certainly not free from criticism, especially given the need to simplify, the general principle remains. An AI system can determine optimal configurations for any system when provided with a range of possibilities for each choice step.

53. To reiterate: building a fully functioning model calls for a preliminary stage where information pertaining to the CEO's production facilities, the production facilities of his competitors, and the overall market are aggregated and fed into the model:

a. Data on the functioning and throughput of the CEO's own production plant will usually be readily available, for instance via bookkeeping records.
b. Details relating to the production facilities, system configurations, and product characteristics of competing firms will be difficult, but not impossible, to come by. Certain facts and figures can be found online. Along these lines, one could think of quarterly earnings reports, financial statements, the location of factories, product measurements, and the number of employees. For other elements, attempts could be made to reverse engineer (parts of) competitors' choice steps or to work with estimates in combination with margins of error.
c. Information related to the grenadine market itself – such as the total addressable market and market penetration levels – can be estimated fairly well on the basis of market research and sales intelligence.

By analysing these (often) publicly available *ripples of information*, the AI system can verify whether a competitor is already operating at an optimal level, or whether he is likely to improve in the near future, relative to the CEO's own operating performance.

54. While some readers may rightfully remain wary or sceptical of these systems, the methodology of finding patterns in big data sets is tried and tested.[118] Big data algorithms have already proven their effectiveness in categorising people and predicting their product preferences, and similar

118 As discussed in M. Broussard, *Artificial unintelligence: How computers misunderstand the world* (Cambridge: MIT Press, 2018), 248 p.; C. O'Neil, *Weapons of Math Destruction: How*

developments are now occurring on the business side of the market as well. To some extent, for instance, a part of a firm's know-how and history can be retraced by simply looking at its decision track record. These public ripples often provide a first step in creating an AI system.

55. Depending on the needs and wants of a particular firm, data scientists might forego some of the more arduous steps in creating a tailor-made AI model. This is especially the case when the necessary data is expensive to come by – timewise or moneywise. In those instances, one could opt to fit system configurations directly to publicly acquired information, albeit with the potential risk of conflating correlation and causation. Such concerns could be overcome by deciding to work with a *rigidly trained AI system*. At the cost of accuracy, human input in these systems can mitigate some of the negative effects of not having access to highly detailed intelligence or big data.

D. Countering Predictability with Inexperience and Complexity

56. The findings from the previous sections indicate that algorithmic conduct may contravene Article 101 TFEU. What is especially noteworthy is that the relevant yardstick for collusion in the context of AI systems seems to revolve around a derivative *requirement of predictability* rather than the traditional benchmark of having a common understanding between competitors. Be that as it may, the competition law toolbox appears flexible and well-equipped enough to cope with instances of algorithmic collusion, given that collusive problems experienced in an algorithmic setting are not fundamentally different from those that occur in a non-algorithmic setting. What is different, though, is that AI systems can parse infinitely more parameters than humans and they can do so without necessarily making those parameters explicit. Hence, as described above, AI systems can inadvertently cast a shroud of fog over collusive conduct whereas colluding entrepreneurs may leave behind a trail of evidence. It is especially this element of attributing collusion to AI that complicates competition enforcement. From a remedial perspective, however, once algorithmic collusion has been established, no significant deviations from established competition law principles are to be expected.

57. Predictability within the market can be counteracted with inexperience and complexity, two approaches which, in effect, are akin to the introduction of new market players and market deconcentration. In those cases, the inexperience of new market entrants and market deconcentration may prevent a common understanding from arising between competitors whilst relying on AI systems.

Big Data Increases Inequality and Threatens Democracy (New York: Crown Publishing, 2017), 254 p.

a. For *experienced players*, it is a given that a firm relies on the assumption that all other market participants will also rely on AI systems, which use similar inputs and which are based on the same general framework. The result is predictability, i.e., the ability to make correct assessments about other actors' commercial conduct.
b. For *inexperienced players*, gaps in terms of know-how are likely to exist. When relying on AI, such models cannot be trained to the same degree of precision than those of experienced players. Inexperienced players' understanding of the market is inherently flawed since they are not yet fully aware of all intricacies and dynamics of the market.

Experienced players may still be able to estimate what a new, inexperienced player is doing on the market given that there is prior knowledge about common pitfalls and challenges that can occur within the sector. Put differently, experience also teaches what can go wrong. This has some notable implications for competition law enforcement.

58. In 2020, the General Court overturned an EC merger decision on the ground that the EC decision was based on the principle that 4-to-3 market player mergers are said to restrict competition by definition.[119] The general principle remains that the (anti)competitive nature of a market is influenced by the number of market players and their respective experience. Given that every market participant influences the available inputs and the market's functioning, the fewer players active in a market, the less complex AI models need to be. Note, however, that this holds true for AI-driven markets as well as non-AI-driven markets and that it corroborates that the finding of an AI infringement poses more serious challenges than resolving the infringement once it is discovered.

59. To further reinforce the market complexity argument, it is useful to briefly venture into the world of chess. In 1997, a chess-playing AI model named Deep Blue was able to defeat reigning world champion Garry Kasparov.[120] While several attempts to dethrone top-tier chess players had already been made in the years preceding the 1997 bout, it wasn't until the late 1990s that AI systems were able to consistently evaluate all chess moves a human player might consider.

Imagine now a three-player chess game. A three-sided game implies that the AI model not only needs to take the reactions of its two human competitors into account, but also how these two players interact with one another. Moreover, the system is further complicated by 'I know that you know' and 'I know that you know that I know' dynamics. This effectively leads to something that can

119 CJEU 28 May 2020, no. T-399/16, ECLI:EU:T:2020:217, *CK Telecoms UK Investments Ltd v European Commission*.
120 X, 'Deep Blue', *IBM*, 2012, https://www.ibm.com/ibm/history/ibm100/us/en/icons/deepblue/.

best be described as an algorithmic *three-body problem*.[121] Undoubtedly, these issues can be resolved by allowing AI to optimise for (more plausible) qualitative solutions rather than tasking AI to brute force all possible configurations. Thus, while feedback loops could go on forever, there are diminishing returns for each additional iteration beyond a certain point. The AI model could thus include logic statements to the effect that the model will halt its calculations once an acceptably low error value has been attained.

60. As recalled, it is not necessary to simulate the entire market in order to make assumptions about a competitor's inner workings. Instead, it is sufficient to consider those ripples of information that concern commercial configurations and changes in these configurations. Nevertheless, since all firms influence the available inputs, any AI system would have to take those other market players into account. It is therefore crucial to state that markets are inherently more obscure with more market players.

When a reasonable amount of computing power is available to firms – and assuming that not every firm has access to a supercomputer – a 4-to-3 merger could mean the difference between a competitive market shaped by unreliable AI predictions and an anticompetitive market shaped by complete transparency.

61. In the judgment referenced above in no. 58, the General Court did not argue that the EC was not entitled to invoke the theory of harm associated with 4-to-3 mergers, but it did hold that the EC should demonstrate the anticompetitive effects of such mergers in this specific sector.[122] Based on this reasoning and in light of the prevalence of AI systems in contemporary markets, such discussions may need to shift towards an assessment of the scarcity of data on relevant parameters for competition (e.g., production costs, R&D, product quality and product prices), rather than the level of competitiveness on the market. In this respect, data scarcity ties into a reduced ability to make accurate predictions about the market conduct of a competitor, which in turn lowers the ability to collude algorithmically with that competitor.

62. In conclusion, the advantages of AI significantly manifest themselves when input data is readily available. While it may not always be possible to prevent ripples of information from being picked up by a competitor's AI system, the general principles of competition law can still provide solace. In that sense, it must be recalled that the intensity of competition on a given market is affected by the number of competitors active on that market. Thus, when input data are

121 While modelling the motion of two objects is relatively straightforward, there is no closed-form solution for modelling the movement of three objects. In this respect, see C. Marchal, *The Three-Body Problem* (Amsterdam, Elsevier Science Publishers, 1990), 592 p.

122 CJEU 28 May 2020, no. T-399/16, ECLI:EU:T:2020:217, *CK Telecoms UK Investments Ltd v European Commission*, paras. 97 and 118.

divided between many competitors, the accuracy of AI predictions is negatively impacted, given the high computational demands of taking many variables into account. Conversely, when there are only a select number of firms active on the market, those firms can accurately monitor and predict each other's behaviour and anticompetitive effects should be assumed. Once market participants' internal behaviour has become fully transparent, any other competitive effects analyses are largely redundant.

Similar views on this topic are expressed elsewhere in literature as well, with authors hinting at divestitures as a potential remedy to counteract instances of algorithmic tacit collusion.[123] Moreover, for the purpose of identifying harmful algorithmic conduct, firms should also be prepared to explain how their AI systems work.[124]

3.3.3. Article 102 TFEU and Abuses of Dominance via AI

63. Apart from cartelisation, another harm to effective competition is governed by Article 102 TFEU. This provision catches abusive conduct by undertakings that hold substantial market power within a given market.[125] The rationale behind Article 102 TFEU is that in instances where one firm (or a small group of firms) possesses high levels of market power, that firm (or group) can act completely independently on the market. The ability to wholly disregard competitors opens the door for dominant firms to unilaterally abuse their privileged position on the market, to the detriment of consumers and competitors alike.

64. Perhaps surprisingly, algorithmic abuse has seen relatively little coverage compared to algorithmic collusion. Some contributions are available on this topic, which mostly focus on the implications of algorithmic pricing and price discrimination under Article 102 TFEU.[126] Nevertheless, even in the face of limited academic coverage, some aspects of AI are worth addressing under Article 102 TFEU.

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123 Beneke and Mackenrodt, 'Remedies for algorithmic tacit collusion', p. 168: '*Structural remedies like divestitures can be used to address concerns of tacit collusion in several ways. A divestiture can aim either at creating a higher number of competitors or at rearranging the competition dynamics between present market participants so that tacit collusion is made more difficult to achieve*'.

124 Competition & Markets Authority, 'Algorithms: How they can reduce competition and harm consumers', *CMA*, 2021, https://www.gov.uk/government/publications/algorithms-how-they-can-reduce-competition-and-harm-consumers/algorithms-how-they-can-reduce-competition-and-harm-consumers.

125 See the references above at fn. 12.

126 E.g., I. Graef, 'Algorithms and Fairness: What Role for Competition Law in Targeting Price Discrimination towards Ends Consumers', *Columbia Journal of European Law*, 2018, vol. 24, no. 3, p. 558; A. Gautier, A. Ittoo and P. Van Cleynenbreugel, 'AI algorithms, price discrimination and collusion: a technological, economic and legal perspective', *European Journal of Law and Economics*, 2020, vol. 50, p. 417.

65. For the proper functioning of AI systems, know-how is extremely important. Without the necessary data, the model cannot be adequately trained, and any predictive results will likely fall short of the desired level of accuracy. This points towards two things. Firstly, larger and more experienced firms will have access to more robust AI models, simply due to having access to more extensive or more specific data for training purposes. Consequently, data provide such firms with a competitive advantage over other market actors. Secondly, larger firms will also have an ability to tip a novel market more easily to their advantage. Their significantly larger datasets provide an opportunity to leverage that data for market tipping purposes.

A. Data as a Competitive Advantage

66. In essence, the possession of data can therefore create a competitive advantage for a firm. Although data are typified as non-exclusive and non-rivalrous goods, the ability to prevent certain competitors from having access to a dataset can provide other undertakings with a competitive edge. This can eventually tie into a positive feedback loop: more data enables a firm to make more accurate predictions. These more accurate predictions put the firm in a position to better serve its customers. This ties into an increased ability to attract new customers. These customers will subsequently also start generating data for the firm. As a result, firms that benefit from extensive market power, are likely able to maintain their dominance via ongoing data collection practices.

67. To illustrate this, it is useful to briefly circle back to the grenadine production facilities from no. 49. Suppose that consumer preferences indicate an appreciable interest in apple-flavoured grenadine rather than strawberry-flavoured grenadine. While the CEO has initially focussed exclusively on producing the traditional, strawberry-flavoured red syrup, he contemplates entering the market for apple-flavoured beverages. He subsequently consults his data engineer, who will likely inform him that the firm's (trained) AI model is robust enough to optimise for very specific results; results which were not necessarily foreseen during the programming stages of the AI. Here, for instance, the CEO could adjust the AI's main task in order to yield the best settings to produce a novel sort of grenadine with a certain flavour palette, while also indicating a suitable price strategy to optimise profits. Once the target is defined, the AI system will parse all possible options and configurations to determine which settings are best suited to attain the predefined goal, here being the production of apple-flavoured grenadine.

68. Two important provisos come to mind. Firstly – as reiterated earlier – an AI model is only capable of optimisation if the general production principles have been adequately described and the options for the various choice steps have been fed into the model. Then, and only then, the model can output the most optimal configuration. This means that an established firm can more rapidly improve their systems and production processes compared to start-ups or small-scale players. Experience in itself will thus allow firms to ramp up their competitiveness with respect to the governing principles of the market. As such, market experience may become a defining barrier to entry into that market, at least in respect of the successful usage of AI.

Secondly, with established firms naturally having more experience (e.g., by virtue of a higher number of client interactions), these firms will encounter more system errors, thus providing them with more opportunities to learn. Again, dominant undertakings will likely have a competitive advantage over smaller players by virtue of their size alone.

69. However, some limitations to this line of reasoning are also worth pointing out. Firstly, even with a high level of technical know-how, one constraint will be the programming complexity of the AI model. With more and more details being added, the model may become unwieldy or computational time might exceed acceptable levels. From that angle, it is fair to assume that the relation between know-how and the performance levels of the AI model cannot be captured by a direct linear relationship. Instead, beyond a certain point, diminishing returns will occur for each additional variable added to the model.

The second limitation lies in the specificity of the model. The fact that know-how of the field is required to train a model also works as a constraint on the model: it will perform well within the sector it was programmed for, but question marks can be put over the transferability of an AI model to a sector that significantly differs in terms of overall structure and functioning. This at least partially does away with concerns about abusive leveraging where dominant firms use their AI models to extend an acquired dominant position to an adjacent market. For completeness's sake, it should be noted that the phenomenon of '*transfer learning*' – i.e., the ability to apply AI's knowledge to a problem that differs from the problem the model was initially trained for – is gaining traction in computer scientific communities.[127]

B. Tipping Markets by Means of Data

70. As the law currently stands, Article 102 TFEU assumes that dominant firms can leverage certain advantages they have obtained by engaging in methods that go beyond competition on the merits. Thus, it is established knowledge that dominant undertakings have a special obligation not to transgress Article 102 TFEU's prohibition of anticompetitive unilateral conduct. Among others, this

[127] F. Zhuang et al., 'A Comprehensive Survey on Transfer Learning', *Proceedings of the IEEE*, 2021, vol. 109, no. 1, p. 43.

suggests that they are prohibited from tipping the market by other means than their productive merits. However, the argument here is that if dominant firms use AI in the ways described above, there would not really be a need to exploit or to leverage on behalf of that firm. Monopolists can quickly outcompete smaller players, simply because they can better assess the importance of certain market characteristics. In other words, those firms can promptly identify which adjustments are necessary in the face of changing market circumstances, whereas smaller, more inexperienced firms do not have this ability.

71. In theory, large undertakings can thus tip markets in their favour without raising any concerns under Article 102 TFEU, since AI allows them to meritoriously optimise their behaviour on the market. This triggers the following question: how should competition law respond? To answer this question, it should first be recalled that the EC does not oppose the existence of large firms – even monopolies – for reasons tied to their size alone.[128] The main criterion is that firms in a dominant position cannot be allowed to harm consumer welfare by means of their commercial conduct.[129] Hence, if a dominant firm can achieve their best results via AI models and without cheating, this should be considered as competition on the merits. Accordingly, the use of AI by a dominant firm does not in itself create a legal ground for competition authorities to intervene. Instead, if 'know-how leveraging' through AI would become a standard practice, it is perhaps useful to reconsider the scope and meaning of the notion 'competition on the merits'.[130]

C. Ongoing Legislative Developments

72. There is increased awareness in both academic and policy circles that data may act as a barrier to market entry.[131] When firms lack the ability to acquire a critical mass of data, there is no real means to effectively compete against incumbent firms. The European legislator has taken note of these challenges and has subsequently launched several initiatives to reassess the balance in digital markets. These legislative proposals attest to a desire to revise the current status quo.

73. The Digital Markets Act (DMA) is a first notable instrument.[132] Among others, the regulation stipulates that firms qualifying as 'gatekeepers'[133] must

128 Whish and Bailey, *Competition Law*, p. 202.

129 CJEU 9 November 1983, no. C-322/81, ECLI:EU:C:1983:313, *NV Nederlandsche Banden Industrie Michelin v Commission of the European Communities*, paras. 10 and 57.

130 In the past, the notion of 'competition on the merits' has already been the subject of different interpretations: M. Stucke, 'What is competition', p. 31.

131 L. Abrardi, C. Cambini and L. Rondi, 'Artificial intelligence, firms and consumer behavior: A survey', *Journal of Economic Surveys* 2021, p. 18.

132 Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act) [2022] OJ L 265/1.

133 Article 3 DMA.

refrain from using, in competition with business users, data which is generated through activities from those business users and which is not publicly available.[134] In a similar fashion, the DMA also sets out that business should have access to data they generate on the gatekeeper's platform.[135] Other data – pertaining, for instance, to aspects such as rankings, search queries and clicks – must be made available to the business by the gatekeeper on fair, reasonable and non-discriminatory terms.[136] While the scope of the DMA is limited to gatekeepers, it does confirm the EU's desire to seek novel legislative solutions for problems originating in data-driven markets.

74. Another noteworthy initiative is the proposed Data Act.[137] Its contents reveal several data sharing obligations, set out conditions under which data holders must make data available to certain recipients, and prohibit the use of assorted contract terms relating to data access and use. One provision, for instance, asserts an obligation to make data generated by the use of products or related services accessible to its users (Article 3), which is combined with a right of those users to access and use those data (Article 4). Those same users are also entitled to share data with third parties (Article 5). Similar to the abovementioned DMA, the proposed regulation aims to ensure that data holders make data available to recipients under fair, reasonable, and non-discriminatory terms.[138] While some carve-outs[139] for micro and small enterprises exist, it is interesting to see that the scope of application of the proposed Data Act includes both business-to-consumer and business-to-business contexts.[140]

4. AI FOR COMPETITION – IMPLICATIONS OF AI FOR ENFORCEMENT

4.1. THE EC ENFORCEMENT TOOLKIT

75. The enforcement of competition law cannot be reduced to a simple game of cat and mouse. Compliance through cooperation rather than punishment appears to be an important credo. The EC's leniency programme captures this idea quite well: by offering cartel members an opportunity to disclose the existence of the cartel, the firm that comes forward with sufficient

134 Article 6(2) DMA.
135 Article 6(10) DMA.
136 Article 6(11) DMA.
137 Proposal for a Regulation of the European Parliament and of the Council on harmonised rules on fair access to and use of data (Data Act), 2022, COM/2022/68 final.
138 Recital 5 Data Act, Article 8 Data Act.
139 Article 7 Data Act.
140 Chapter II Data Act.

inculpatory evidence may obtain full immunity.[141] Additionally, the EC can adopt Commitment Decisions under Regulation 1/2003 in view of ensuring an undertaking's compliance with competition law.[142] Hence, the cat and mouse metaphor does not fully hold true, considering the various cooperative tools available to the EC to maintain effective competition on the market. Nevertheless, for the purpose of this chapter it is helpful to make an abstraction of these considerations and to work with the hypothesis of firms acting in bad faith and enforcement authorities seeking to aggressively counteract anticompetitive conduct.

4.2. INVOLVING AI MODELS IN THE ENFORCEMENT OF COMPETITION LAW

76. When pursuing enforcement actions against anticompetitive firms, it is well established that the EC relies on economic computer models.[143] For instance, the EC models the impact of specific mergers, checks for specific competition law infringements, or scrutinises certain markets for suspiciously stable prices.[144] Naturally, as computer techniques evolve beyond simple linear regression models, it is reasonable to assume that the EC will incorporate AI in their enforcement toolkit.

77. Little additional details are needed to understand that the EC can also use the ripples of information generated by firms to seek for specific anticompetitive behaviour. Gun jumping[145] affords us a good example in this regard. Given the number of people and countless hours of administrative work involved in mergers, some derivative effects are very likely to be noticeable.

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141 Commission Notice on Immunity from fines and reduction of fines in cartel cases [2006] OJ C 298/17; A. Stephan, 'An empirical assessment of the European Leniency Notice', *Journal of Competition Law & Economics*, 2008, vol. 5, no. 3, p. 538.

142 Council Regulation (EC) No 1/2003 of 16 December 2002 on the implementation of the rules on competition laid down in Articles 81 and 82 of the Treaty [2003] OJ L 1/1, article 9.

143 Notable research on this topic has been performed by Wouter Wils: W. Wils, 'The European Commission's 2006 Guidelines on Antitrust Fines: A Legal and Economic Analysis', *World Competition: Law and Economics Review*, 2007, vol. 30, no. 2, p. 14 ff; W. Wils, 'Optimal Antitrust Fines: Theory and Practice', *World Competition*, 2006, vol. 29, no. 2, p. 30–32; see also G. Massarotto and A. Ittoo, 'Gleaning Insight from Antitrust Cases Using Machine Learning', Stanford Computational Antitrust, 2021, vol. 1, p. 37.

144 W. Wils, 'Optimal Antitrust Fines: Theory and Practice', pp. 7–8.

145 Gun jumping encompasses practices relating to the unlawful coordination between firms prior to a merger or the failure to notify the merger to the relevant competition authorities in a timely manner.

4.2.1. Procedural Limitations

78. At the same time, the EC will also face some of the constrains experienced by new market entrants or smaller-scale firms: they might lack the industry-specific knowledge to truly grasp which choice steps firms can go through. However, this has always been the case and the proliferation of AI does not introduce new challenges in this respect. This also explains why the EC conducts sector inquiries, dawn raids, and why the EC has the authority to issue requests for information, albeit within the bounds of the relevant procedural restrictions contained in Regulation 1/2003.[146] The limitation vis-à-vis such requests for information is that the EC has to (i) communicate the legal basis for the request, (ii) specify the request's purpose, (iii) indicate which information needs to be provided within a given timeline, and (iv) mention the relevant penalties in case of non-compliance.[147] Furthermore, the prohibition for the EC to engage in fishing expeditions should also be kept in mind.[148] Asking for information without a specific reason would not be permitted. The opposite holds true if the EC has solid reasons to believe it could find evidence of anticompetitive conduct in a firm's AI models.

4.2.2. Building and Using AI-based Enforcement Tools

79. While no precedents are available on this topic, there does not seem to be a legal reason barring the EC from inquiring about a firm's AI models and its training data – for the purpose of a competition investigation or perhaps also for the purpose of building their own regulatory AI enforcement tools – save for the requirement to communicate the purpose of the request for information.[149] While a firm can refuse to grant access to the relevant information, such behaviour could prompt the EC to issue a Commission Decision to force the firm to comply. On the one hand, at this point, the targeted firm could try to seek recourse before the European Courts to invalidate the EC Decision. On the other hand, a refusal to cooperate could quality as an aggravating circumstance in the context of infringement cases.

More procedurally oriented research could further describe the conditions under which the EC may overcome its know-how limitations in view of creating a level playing field for competition enforcement purposes. Yet, in doing so, the procedural and practical barriers should not be overlooked. For AI models specifically, the principle remains that you 'learn by doing', implying that

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146 The different powers of investigation accorded to the EC are listed in Chapter V of Regulation 1/2003. The provisions mentioned there also touch on several procedural limitations.

147 Regulation 1/2003, articles 18.

148 CJEU 18 June 2015, no. C-583/13 P, ECLI:EU:C:2015:404, *Deutsche Bahn and Others v Commission*, para. 67.

149 Regulation 1/2003, article 20.

active firms will likely always have an informational edge over competition enforcement authorities.

80. At an earlier point in this chapter, concerns about evidence of anticompetitive conduct drying up due to AI were addressed.[150] Yet, even if firms no longer produce a paper trail of their cartel, the source code of the AI model still forms part of the firm's records. Thus, once the EC becomes aware that certain firms possess AI systems, they could request information about the source code and verify the model's functioning and performance against flagrant types of cartel abuses. Traditional restrictions by object might still be easily proven this way. This is the case, for instance, when an AI model recommends a specific configuration that would allow a firm to compete on prices more aggressively, yet the firm refuses to lower its prices since it knows other firms will not do so either.

81. Yet, firms are entitled to use publicly available information to determine their competitive strategy.[151] This suggests it may be difficult to confirm anticompetitive conduct by merely referring to the AI's source code and output. For instance, firms' internal AI-based strategic decisions are sometimes difficult to qualify as a concerted practice, simply because the decision is the most rational. If two competing ice cream shops are considering expanding to new locations and they know where the other firm is likely to move – based on preparatory actions generating ripples of information for AI to pick up –, then it would be bad management to not take this information into account when deciding on a new venue. As noted earlier, drawing a line between tacit collusion and intelligent adaptation in such instances remains a difficult task.[152]

82. A final element that needs to be addressed is the predictability of the EC's actions. It is not inconceivable that the EC also generates certain ripples of information, be it by employing staff members with a specific expertise, adopting administrative decisions, or initiating legal actions. From that perspective, firms or their legal counsels might attempt to monitor what the EC is doing in an anticipatory move. A determined cartelist could, for instance, devise a system to assess the risk of a dawn raid or estimate the chances of being targeted via a sector inquiry.

5. CONCLUSION

83. The underlying theme throughout this chapter is predictability. Some confusion and misconceptions exist surrounding the level of predictability of

150 See above at no 45.
151 Which is the argument made on the use of pricing algorithms by Schwalbe, 'Algorithms, Machine Learning, and Collusion', pp. 594–596.
152 See above at no. 40.

AI systems. The chapter sets out to do away with this confusion by putting AI's (pseudo)-randomness into context and by arguing that AI does not act inherently unpredictably. Furthermore, it was emphasized that the proper functioning of an AI system hinges on two factors. Firstly, the AI model's programmer should have sufficient knowledge of the principles of the sector wherein the AI model will operate. Secondly, sufficient time needs to be spent on feeding the model with the possible options for the various choice steps. When both conditions are met, the AI model will in principle be able to indicate a firm's optimal commercial strategy in a given market.

84. A first implication of using AI relates to algorithmic collusion. Commercially sensitive decisions are likely to generate ripples of information within the sector. Firms can rely on their AI models to detect such signals and to derive or predict possible decision strategies of their competitors. The use of AI thus puts strain on the existence of information asymmetries on the market. These effects tie into concerns about algorithmic collusion; concerns which are dealt with under Article 101 TFEU and which usually involve the unlawful exchange of information between competitors. Since direct contact between firms is no longer required to identify each other's conduct on the market, little to no evidence exists to corroborate findings of anticompetitive decision-making, except for evidence inferred from the AI model itself.

85. A second implication of the proliferation of AI in commercial settings is that know-how could be leveraged to make a firm and its products objectively best adapted to its market. AI can identify optimal product characteristics and specify how these characteristics can be attained given the constraints within the sector and considering a firm's productive limitations. The result is that established players and large undertakings have a clear advantage compared to new market entrants and small-scale undertakings. Established, dominant players will generally have more experience and knowledge of a sector's inner workings and have a better, more in-depth understanding of how certain choice steps can play out. Hence, such firms will be quicker and more effective in optimising their commercial strategy and products on the market, thereby enabling them to remain in the lead. While interesting to consider these implications under Article 102 TFEU, these firms will have no need to exploit or leverage their market power. Instead, combining AI with dominant firms' superior levels of market know-how will already guarantee their sustained competitive advantage. As the law currently stands, Article 102 TFEU does not prohibit tipping the market via such methods, as the market is objectively won by the dominant firm via competition on the merits.

86. A third implication of AI concerns competition enforcement. In that regard, what applies for firms, also applies for the EC. The EC – as well as NCAs

– could theoretically identify firm's (anticompetitive) conduct on the basis of ripples of information tied to such conduct. However, in this respect, the EC will face some of the constraints that smaller firms also experience, namely that it will have trouble creating AI systems that can attain insider levels of accuracy. Competition authorities could issue a request for information pertaining to the AI model's source code, yet procedural and practical limitations emerge. Additionally, firms could task their AI systems to estimate the risk of being involved in EC antitrust investigations. This, together with the potential dry up of direct evidence of anticompetitive behaviour, might give the EC a hard time in bringing future antitrust cases.

87. The increasing use of AI in commercial settings triggers interesting questions, both from a legal and policy perspective. At present, concerns about 'super AIs' – AIs which are orders of magnitude smarter than humans – are overblown, simply because they are not (yet) on the horizon. However, current conceptualisations of AI give rise to a serious problem for competition law, namely AI's ability to remove information asymmetries for experienced market participants. On the one hand, the core function of AI is to make predictions about competitors' conduct. On the other hand, unpredictability within the market is crucial to the process of effective competition.

88. Despite the challenges created by AI, competition scholars may find solace in knowing that the body of competition law is flexible enough to cope with algorithmic conduct. For algorithmic collusion, it was shown that a deviation from established case law principles may be appropriate in order to prevent future instances of algorithmic tacit collusion from escaping the ambit of Article 101 TFEU. For algorithmic abuses of dominance, it was recalled that the possession of a dominant position is not prohibited as such and that the extensive use of AI remains perfectly legitimate when committing to competition on the merits. Nonetheless, there is increased awareness that data may act as a barrier to market entry and that limited access to data can put strain on the competitive process. Future discussions on this topic are therefore likely to be shaped by legislative initiatives such as the Digital Markets Act and the Data Act, which stipulate data sharing obligations and set out conditions under which data holders must make data available to other market actors. For competition enforcement, topical issues revolve around strengthening the investigative powers of competition authorities and making sure that sufficient resources and know-how are available to effectively respond to threats of anticompetitive practices that occur via AI. The conclusion of this chapter is therefore as follows: *competition law and AI are indeed on a collision course, but a head-on collision can be averted by making minor course corrections.*

APPENDIX

EUCLID'S ALGORITHM

89. In order to discover the greatest common divisor (GCD) of two numbers *a* and *b*, we start by dividing *a* by *b*. This division results into a quotient *q* and a remainder *r*. The value of *a* can subsequently be rewritten as follows: $a = q * b + r$. At this point, two options are possible:

a. If the value of *r* equals zero, the algorithm stops and the GCD of *a* and *b* is found to be *b*.
b. If the value of *r* does not equal zero, the algorithm continues by writing the value of *b* to variable *a*, and by writing the value of *r* to variable *b*. The while-loop will continue with its next iteration, until *r* eventually reaches either 0 (and the *while*-loop stops) or 1 (and *r* triggers the *break*-condition within the *while*-loop).

90. This algorithm – colloquially known as Euclid's algorithm – can be coded in Python as follows.

```
a = int(input("Number 1:"))
b = int(input("Number 2:"))
while 1:
    r = a%b
    if not r:
        break
    a = b
    b = r
print("The greatest common divisor is:", b)
```

91. When the algorithm is applied to $a = 19$ and $b = 8$, it is found that the GCD = 1. Since *r* is constrained to non-zero values, the *break*-condition within the *while*-loop will trigger during an attempted 4th iteration.

Iteration 1:	19 / 8 = 2 * 8 + 3
Iteration 2:	8 / 3 = 2 * 3 + 2
Iteration 3:	3 / 2 = 1 * 2 + 1
Iteration 4:	2 / 1 = 2 * 1 + 0 (suppressed)

92. When the algorithm is applied to $a = 12$ and $b = 6$, it is found that the GCD = 6. Note that the *break*-condition within the *while*-loop is already triggered during the 1st iteration, given that *r* is zero. No 2nd iteration of the *while*-loop is attempted.

Iteration 1:	12 / 6 = 2 * 6 + 0 (suppressed)

THE MARKET FOR GRENADINE

93. The pseudo-code for the 'market for grenadine'-AI model. Annotations are listed as triple-quoted strings and typeset in italics.

```
''' An assortment of variables (fruits, supplier_1, equalise_fruit_and_water, …) is created
and written to memory. These variables concern the relevant production factors and are
subsequently linked to a specific category (inputs, suppliers, production_steps, …). '''

inputs = (fruits,
          sugar,
          water,
          spices)

suppliers = (supplier_1,
             supplier_2,
             supplier_3,
             farmer_1,
             farmer_2,
             farmer_3,
             shop_1,
             shop_2,
             shop_3)

production_steps = (equalise_fruit_and_water,
                    boil_fruit_and_water,
                    test_fruit_boil,
                    sift_fruit_water,
                    discard_waste,
                    sift_first_extract,
                    boil_extract,
                    add_sugar_extract,
                    boil_sugar_extract,
                    cool_down_warm_grenadine,
                    bottle_grenadine,
                    cool_down_grenadine)

intermediary_steps = (human_action,
                      conveyor_action,
                      external_action)

preparatory_steps = (setup_cauldron,
                     setup_fire_a,
                     setup_fire_b,
                     setup_fire_c,
                     setup_sift,
                     set_new_cauldron,
                     set_cauldron_cool_place,
                     set_empty_bottle,
                     set_trench,
                     set_cool_bottle_place)

''' A well-defined target (executive_target) and target constraints (consumer_preference)
are introduced. At a later stage, the AI model will rely on these parameters to find a
```

```
combination of input variables that is not only deemed 'most suitable', but that also
adheres to specified decision boundaries. '''

executive_target = profit_target

consumer_preference = (flavour,
                       process_appreciation)

''' The section below defines a function (optimal_supply_chain_process) that, considering
all available inputs, determines what the most desirable commercial strategy is. This
process consists of several sub-steps:
    1. Firstly, the system checks which combinations can be formed with the provided
       input values.
    2. Secondly, the system assigns a score to each combination of input values.
    3. Thirdly, the system calculates the difference between the assigned scores and
       the desired outcome.
    4. Fourthly, the system returns as its output the configuration of input values with
       the smallest error, i.e. the configuration of input values with an assigned score
       that best approximates the desired outcome. '''

def optimal_supply_chain_process(inputs,
                                 suppliers,
                                 production_steps,
                                 intermediary_steps,
                                 preparatory_steps,
                                 executive_target,
                                 consumer_preference):
        error = [1,0,2]

        while error[0] > error[1] and error[0] < error[2]:
          for product in inputs:
            product_supplied.append(AI_choose_supplier(product, suppliers))
              for step in production_steps:
                agent_work.append(AI_choose_between_step(step,
                intermediary_steps))
              for preparation in production_steps:
                agent_work_two.append(AI_choose_preparation(preparation,
                intermediary_steps))

        unit_costs = calculcate_grenadine_cost(product_supplied,
                                               agent_work,
                                               agent_work_two)

        appreciation_score = calc_grenadine_appreciation(
                                agent_work.append(
                                agent_work_two),
                                consumer_preference[1])

        grenadine_taste = calc_grenadine_taste_flavor(product_supplied)

        if grenadine_taste.sour_limit > consumer_preference.sour_limit:
          error.insert(0,100)
          next
        elif grenadine_taste.sweet_limit > consumer_preference.sweet_limit:
          error.insert(0,100)
```

```
            next
        else:
            taste_score = taste_overlap(grenadine_taste.key_features,
            consumer_preference[0].key_features)

        for work in agent_work:
            if work.actor == conveyor_action:
                try:
                    automation_dictionary[work.name]
                except:
                    error.insert(0,100)
                    next

        for work in agent_work_two:
            if work.actor == conveyor_action:
                try:
                    automation_dictionary[work.name]
                except:
                    error.insert(0,100)
                    next

        current_variables = (product_supplied,
                             agent_work,
                             agent_work_two)

        most_profitable_configuration = ai_set_price_and_markettest(
                                            unit_costs,
                                            appreciation_score,
                                            taste_score)

        error.insert(0, abs(executive_target – most_profitable_configuration))

        return (current_variables, most_profitable_ configuration)
```

''' Analogous to the steps performed above, estimated input values for a competitor are specified and parsed by the function 'optimal_supply_chain_process'. The function makes an estimation as to the competitor's ideal price. '''

```
competitor_ideal_price = optimal_supply_chain_process(inputs,
                                                      suppliers,
                                                      production_steps,
                                                      intermediary_steps,
                                                      preparatory_steps,
                                                      executive_target,
                                                      consumer_preference)
                                                      [1].price
```

''' The model compares the competitor's ideal price with your own price. Accounting for a margin of error and in light of your own and your competitor's input parameters, the difference between the two resulting values provides an indication as to what the competitor might be doing:

- *The competitor has a production process similar to your own and charges similar prices.*
- *The competitor has a production process similar to your own and charges lower prices. The competitor may be anticompetitively selling at a loss.*

```
    – The competitor has a better production process relative to your own and charges
      similar prices. The competitor may lower its prices in the future to attract more
      customers.
    – The competitor has a better production process relative to your own and charges
      lower prices. The competitor may have access to technology which you do not
      possess. '''

if competitor_ideal_price!= competing.price + model_margin_up or competitor_
ideal_price!= competing.price – model_margin_down:
    if competitor_ideal_price > competing.price + model_margin_up:
        print("competitor likely has already improved production system by technology we
         are unaware of")
    if competitor_ideal_price < competing.price – model_margin_down:
        print("competitor can improve their production method and is likely to lower its
         prices – or might be acting anticompetitively")
```