Stanford Computational Antitrust

ARTICLE

Computational Antitrust: An Introduction and Research Agenda

Dr. Thibault Schrepel, LL.M.*

Abstract. Computational antitrust is a new domain of legal informatics which seeks to develop computational methods for the automation of antitrust procedures and the improvement of antitrust analysis. The present article first introduces it, then explores how agencies, policymakers, and market participants can benefit from it. Against this background, it sets out a research agenda for the years ahead in view of providing answers to the challenges created by computational antitrust, and better understand its limits.

* Faculty Affiliate at Stanford University CodeX Center (creator of the project on Computational Antitrust), Assistant Professor at Utrecht University School of Law, Associate Researcher at University of Paris 1 Panthéon-Sorbonne, and Invited Professor at Sciences Po Paris. I express my deepest gratitude to my friend Nicolas Petit for his comments on the draft version of this article. I would also like to thank Catalina Goanta, Kirill Ryabtsev, and Martin James Sicilian for their suggestions, and Roland Vogl for encouraging me to start a new project at the CodeX Center. This article serves as an introduction to it. Lastly, I am grateful that many professors and antitrust agencies have agreed to take part in this project. No outside funding was received or relied upon for this paper.

Introduction

Antitrust 1.0 appeared in 1890 with the Sherman Act and was introduced in Europe with the Treaty of Rome in 1957. It has been shaped by several schools of thought (antitrust 1.1 for the Brandeis School, antitrust 1.2 for the Roosevelt School…), but always within the framework of a textual interpretation. Antitrust 2.0 then came along with the Chicago School in the early 1960s (antitrust 2.1 being the Harvard School, antitrust 2.2 the post-Chicago School…). Antitrust law became more economical to fit with the dynamic sectors falling within its scope. The method matched the subject matter.

Antitrust 3.0 is emerging but remains incomplete. It appeared in the early 2010s when antitrust agencies have shifted their focus on the issues related to the digital economy. But while there are passionate discussions about the practices implemented by digital players, the use of technological tools to address them is very little debated. This disconnection between diagnosis and treatment is becoming problematic. Antitrust agencies struggle to remedy anticompetitive practices in increasingly complex, fast-paced, and evolutive markets. Soon, firms will also suffer from this struggle leading to fewer decisions and well-informed guidelines. Legal certainty will decrease while the number of judicial errors will be on the rise. Against this background, one must increase antitrust law with new technologies to make antitrust 3.0 complete. Enters "computational antitrust."[1] The present article first explains what it is (**I**) before discussing its potential (**II**), and the challenges ahead (**III**).

I. What is Computational Antitrust?

First, this article discusses the core idea and concepts behind computational law (**A**), after which it introduces computational antitrust (**B**). As one shall explain, the challenges encountered by the jurists, philosophers, and mathematicians in computational law matters are also found in computational antitrust.

A – Computational Law

Computational law is a "branch of legal informatics concerned with the mechanization of legal analysis (whether done by humans or machines)."[2] Computational law is today a subject of growing enthusiasm,[3] although the idea to compute the law is centuries old. German philosopher Gottfried Wilhelm Leibniz (1646–1716), known for his defense of rationalism, argued in the 17th century that each legal question has a single answer.[4] From then on, "if controversies were to arise, there would be no more need of disputation between two philosophers than

[1] *See* https://law.stanford.edu/computationalantitrust for more information about the Computational Antitrust project at Stanford University, CodeX Center (The Stanford Center for Legal Informatics).
[2] Michael Genesereth, *Computational Law: The Cop in the Backseat* (2015). *See* also Nathaniel Love & Michael Genesereth, *Computational Law* (2005) ("The techniques of computational logic, applied to the semantic rules as well as the data, form the basis of a computational law system").
[3] Google Books, Ngram Viewer, archived at https://perma.cc/9HPD-QXEU#t1%3B%2Ccomputational%20law%3B%2Cc0.
[4] Hanina Ben-Menahem, *Leibniz on Hard Cases*, 79 ARCH. RECHTS SOZIALPHILOS 198, 209 (1993).

between two accountants. For it would suffice for them to take their pencils in their hands and to sit down at the abacus and say to each other (with a friend if they wish): Let us calculate."[5]

Other philosophers like Jeremy Bentham also argued that codifying the law would help make it more practical and accessible[6]—which Emperor Napoleon did in France.[7] With that in mind, Leibniz and his descendants always faced the difficulty of codifying the entire law, which, being the product of natural languages, could not be fully consolidated. Today, digital technologies give new life to these ambitions aspiring to mechanize the rule of law in its entirety (enforcement included).[8] Of course, technologies are subject to combinatorial evolution, making it very difficult to forecast which form they will take.[9]

One can nonetheless imagine a world in which artificial intelligence ("AI")[10] and blockchain combined with quantum computing will soon provide valuable support by enabling a better understanding of the world's complexity, and eventually, capturing *part* of it. Today already, multiple computational tools are currently being deployed in legal fields, such as data mining, machine learning, deep learning simulations, natural language techniques, social epidemiology, document management, legal text analytics, computational game theory, network analysis, and information visualization.[11] These tools capture rich and detailed data about the external world, make them computable,[12] and process them to reach a broader and more granular level of analysis.[13]

[5] GOTTFRIED WILHELM LEIBNIZ, DISSERTATIO DE ARTE COMBINATORIA (1666).

[6] Dean Alfange Jr., *Jeremy Bentham and the Codification of Law*, 55 CORNELL L. REV. 58 (1969). In that regard, common law might be more complex to compute than civil law, *see* Sarah B. Lawsky, *Formalizing the Code*, 70 TAX L. REV. 377, 379 (2017) (stressing that formalization "could help move the law closer to legibility by a computer"). Also, *see* Mark A. Lemley, *The Law and Economics of Internet Norms*, 73 CHI.-KENT L. REV. 1257, 1294 (1998) (arguing that common law is "doing a pretty good job of adapting existing law to the new and uncertain circumstances of the Net").

[7] Ross Levine, *Law, Endowments and Property Rights*, 19 J. ECON. PERSP. 61, 63 (2005).

[8] Michael A. Livermore, *Rule by Rules*, *in* COMPUTATIONAL LEGAL STUDIES: THE PROMISE AND CHALLENGE OF DATA-DRIVEN RESEARCH 238, 261 (Ryan Whalen ed., 2020).

[9] W. BRIAN ARTHUR, THE NATURE OF TECHNOLOGY: WHAT IT IS AND HOW IT EVOLVES 18 (2010).

[10] Catalina Goanta, Gijs van Dijck & Gerasimos Spanakis, *Back to the Future: Waves of Legal Scholarship on Artificial Intelligence*, *in* TIME, LAW, AND CHANGE AN INTERDISCIPLINARY STUDY 329, 335 (Sofia Ranchordás & Yaniv Roznai eds., 2020) (creating a timeline of what the authors call "A Brief History of Artificial Intelligence" and showing an increase in the popularity of artificial intelligence in the academic literature, especially after 2016).

[11] *See* Nicola Lettieri, et al., *Ex Machina: Analytical platforms, Law and the Challenges of Computational Legal* Science, 10 FUTURE INTERNET 37, 39 (2018) (listing several of these tools). For a larger database (also including non-computational tools), *see* Legaltechlist, https://techindex.law.stanford.edu/, archived at https://perma.cc/9WT8-PJNY. On the subject of deep learning, *see* Blagoj Delipetrev, et al., *Historical Evolution of Artificial Intelligence*, EUR 30221EN, Publications Office of the European 12 (2020) (explaining that deep learning involves artificial neural networks and the use of multiple layers). On legal text analytics, *see* GitHub, *Legal Text Analytics* https://github.com/Liquid-Legal-Institute/Legal-Text-Analytics, archived at https://perma.cc/7VY9-8F6E. Explaining how these tools, such as machine learning, will increase trust in our institutions, *see* Balázs Bodó, *Mediated trust: A Theoretical Framework to Address the Trustworthiness of Technological Trust Mediators,* NEW MEDIA & SOCIETY 13 (2020) (arguing that "[m]achine learning-based systems produce trust from insight" by providing more data and transparency in the way they are analyzed).

[12] On this subject, *see* How AI could help market intelligence gathering, Commission tender COMP/2017/017 (Consultancy "Artificial Intelligence Applied to Competition Enforcement"), October 2017, available on Commission, *Contracts > Ex-ante Publicity on Low and Middle Value Contracts*, European Commission: Competition, https://ec.europa.eu/competition/calls/exante_en.html, archived at https://perma.cc/M6Z5-8YT3.

[13] *See* European Commission *supra* note 11. Also, J.B. Ruhl & Daniel Martin Katz, *Measuring, Monitoring, and Managing Legal Complexity*, 101 IOWA L. REV. 191 (2015) (identifying potentially useful metrics and methods for measuring or monitoring legal complexity).

In the end, all pointers indicate that computational methods will first supplement the functioning of our legal system and will end up taking over a large part of it.[14] This substitution process will trigger critical questions. Getting ready for it—and, eventually, for shaping it—requires discussing which principles ought to be preserved and developed. The study of computational law as a complement, which it currently is (i.e., a way to automate processes and improve existing analyses), might be our best shot at it.

B – Computational Antitrust

Markets are becoming increasingly complex and dynamic in today's economy.[15] This complicates the task of antitrust agencies, each day a little more. Against this background, the implementation of computational methods is becoming necessary to maintain and improve antitrust agencies' ability to detect, analyze, and remedy anticompetitive practices.[16]

These tools and methods are rarely used in antitrust law today, in fact, most antitrust agencies are just beginning to acquire the technical expertise to develop and use them. Eventually, computational tools should be widely adopted and allow the integration of more variables in anticompetitive cases, whether from economic theory, business and management science, computer science, statistics, or behavioral insights.[17] These tools will also simplify merger control, freeing up some of the teams within each antitrust agency. Accordingly, one must want to explore where and how to develop computational antitrust—a specialist field of computational law that purports to improve antitrust analysis and procedures by assistance of legal informatics.[18]

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[14] Commission White Paper On Artificial Intelligence – A European Approach to Excellence and Trust (Brussels, 19.2.2020) (COM(2020) 65 final) 8 (2020) (underlining the need for public services to make use of artificial intelligence).

[15] David J. Teece, Gary Pisano & Amy Shuen, *Dynamic Capabilities and Strategic Management*, 18 STRATEG. MANAG. J. 509, 515 (1997). Also, *see* Friedrich August von Hayek, *The Theory of Complex Phenomena*, *in* READINGS IN THE PHILOSOPHY OF SOCIAL SCIENCES 55, 56 (1994) (defining complexity as the number of elements determining a pattern). For empirical studies, *see* Statista, *Digital Economy Compass* 6 (2019) (showing that the total amount of data generated across numerous digital layers was 33 zettabytes in 2018. It may grow to 175 in 2025, over 600 in 2030, and over 2,100 in 2035). Documenting the exponential growth of numerous digital industries such as eCommerce, FinTech, digital advertising, cloud hosting, and smart home, *see* Statista, *Digital Economy Compass* 133-243 (2020). Lastly, documenting markets' dynamism at the national level, *see* the OECD *Insights on Productivity and Business Dynamics* https://www.oecd.org/sti/ind/oecd-insights-on-productivity-and-business-dynamics.htm, archived at https://perma.cc/A4CJ-MGMG.

[16] Richard A. Posner, *The Decline of Law as an Autonomous Discipline: 1962-1987*, 100 HARV. L. REV. 761, 777 (1987) (explaining that "despite all the false starts and silly fads that have marred its reaching out to other fields, the growth of interdisciplinary legal analysis has been a good thing, which ought to (and will) continue").

[17] They enable "the man of the future" such as described by Oliver Wendell Holmes, *The Path of the Law*, 10 HARV. L. REV. 457, 468 (1897) (explaining that "[f]or the rational study of the law, the black-letter man may be the man of the present but the man of the future is the man of statistics and the master of economics").

[18] As I shall explain in this article, "better" (mainly) means faster and more accurate, in short, closer to the analog world.

II. The Potential of Computational Antitrust

The development of computational antitrust benefit enforcers, policymakers, and companies in all areas of antitrust law. That applies to anticompetitive practices (**A**), merger control (**B**), and the design or monitoring of antitrust policies (**C**).

A – Anticompetitive Practices

First, computational tools benefit agencies by increasing the availability of data about markets. In doing so, they help creating new forensics capabilities by increasing the flow of information available to agencies (therefore reducing Hayekian informational asymmetries), and, as a result, improving their ability to *detect* antitrust infringements.[19]

These tools are most welcomed considering that antitrust agencies are (to this day) mostly relying on reactive methods (such as leniency applications) for detecting collusion[20] whereas their effectiveness is declining.[21] Considering that technologies—such as powerful AI systems and blockchain—help market players implement and sustain their anticompetitive practices, the use of computational tools (as a proactive response) is becoming necessary.[22]

Against this background, the development of new market screening tools could help to identify anticompetitive patterns and behaviors.[23] Machine learning will

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[19] As reported by Matthew Newman*, Online Pricing Algorithms Prompt EU Antitrust Regulator to Boost Detection Tools*, MLEX (Sept. 24, 2018), Margrethe Vestager underlined that the European Commission could "make more use of algorithms in order to be able to police or supervise what's going on in the marketplace." She shared the same desire a few months earlier in Brussels according to Foo Yun Chee, *EU Considers Using Algorithms to Detect Anti-Competitive Acts*, REUTERS (May 4, 2018) (declaring, "we *would like* to have our own algorithms to be out there") [emphasis added]. As reported by Maxwell Fillion & Rodrigo Russo, Alexandre Barreto de Souza (The Administrative Council for Economic Defense's President) said during the GCR Live 8th Annual Antitrust Law Leaders Forum in February 2019 that he was pushing the agency toward "continuous investments on tools and investigative techniques (...) capable of detecting cartels and other anticompetitive conduct," *CADE Investing in New Tools, 'Brain Project' to Combat Bid-Rigging*, MLEX (Feb. 1, 2019). As reported by Matthew Holehouse, the CMA is currently developing tools to monitor digital platforms' compliance with competition law, *Competition Regulators Need AI and Behavior Experts*, MLEX (Jun. 24, 2019). Discussing how AI could help the detection of anticompetitive practices, *see* Lance B. Eliot*, Antitrust and Artificial Intelligence (AAI): The Antitrust Vigilance Lifecycle and AI Legal Reasoning Autonomy* (2020). In short, computational tools will lead antitrust to get its Billy Beane moment, *see* MICHAEL LEWIS, MONEYBALL: THE ART OF WINNING AN UNFAIR GAME (2003).

[20] OECD, *Ex Officio Cartel Investigations and the Use of Screens to Detect Cartels* 9, 108 (2013).

[21] *See* Johan Ysewyn & Siobhan Kahmann, *The Decline and Fall of the Leniency Programme in Europe*, 1 COMP. L. REV. 44, 45 (2018) ("In 2014 there were 46 leniency applications, which dropped to 32 applications in 2015, and finally only 24 applications have been registered in 2016"); Charles McConnell, *Type A Leniency Applications Down, US DOJ Official Says*, GLOBAL COMPETITION REV. (Jun. 15, 2018), https://globalcompetitionreview.com/article/1170614/type-a-leniency-applications-down-us-doj-official-says, archived at https://perma.cc/ZT6J-7NER.

[22] *See* Thibault Schrepel, *Collusion by Blockchain and Smart Contracts*, 33 HARV. J.L. & TECH. 117, 159 (2019) (explaining how blockchain could increase cartels' stability).

[23] The Competition and Markets Authority, for example, has developed a monitoring tool to track and monitor RPM in the musical instruments sector, *see* CMA, *Restricting resale prices: how we're using data to protect customers* (Jun. 29, 2020) https://competitionandmarkets.blog.gov.uk/2020/06/29/restricting-resale-prices-how-were-using-data-to-protect-customers/, archived at https://perma.cc/JV89-LXTB. Generally, on the use of computational tools for detecting cartels, *see* Andreas von Bonin & Sharon Malhi, *The Use of Artificial Intelligence in the Future of Competition Law Enforcement*, 11 J. EUR. COMP. L. & PRAC. 468, 470 (2020); Melissa S. Baucus & Janet P Near, *Can Illegal Corporate Behavior Be Predicted? An Event History Analysis*, 34 ACAD. MANAGE. J. 9, 11 (1991) (discerning industry patterns in which antitrust violations are more likely); *see* Michal Gal, *Algorithms as Illegal Agreements*, 34 BERKELEY TECH. L.J. 67, 115 (2019) (stressing that "enforcement is likely to become an up-hill battle"); Lilian Petit, *The Economic*

prove helpful in that regard.[24] Techniques of natural language understanding could also automate the identification of illegal intentions when analyzing companies' internal documents.[25] The more complex (and dynamic) the practices, the more useful these tools will be.[26] In the long term, one can imagine that application programming interfaces ("APIs") will facilitate the transformation of data into information and create new channels for the automatic sending of certain data from companies to agencies, and vice versa.[27]

Second, computational tools enable agencies to process data more efficiently and *understand* practices better.[28] They are indeed improving the speed by which

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Detection Instrument of the Netherlands Competition Authority (2012); Ai Deng, *Cartel Detection and Monitoring: A Look Forward*, 5 J. ANTITRUST ENFORC. 488, 494 (2017) (discussing how statistical test-based screens could help dynamic and real-time cartel detection); and Rosa M. Abrantes-Metz & Albert Metz, *Can Machine Learning Aid in Cartel Detection*, ANTITRUST CHRON. COMPETITION POL'Y INT'L Dec. 2018, at 1, 3 (calling "cartel detection" a problem of classification). More specifically, on cartel rigging, *see* Martin Huber & David Imhof, *Machine Learning with Screens for Detecting Bid-Rigging Cartels*, 65 INT. J. IND. ORGAN. 277 (2019); Sanchez-Graells A, *"Screening for Cartels" in Public Procurement: Cheating at Solitaire to Sell Fool's Gold?*, 10 J. EUR. COMP. L. & PRAC. 199, 199 (2019); Autorité de la Concurrence & Bundeskartellamt, *Algorithms and Competition* 65 (2019) ("competition authorities could develop their own machine-learning algorithms to detect algorithmic collusion (...) competition authorities of Brazil, Germany, Mexico, Portugal, Russia, South Korea, Spain, Switzerland and the United Kingdom have used data screening techniques to assist in detecting cartels"). For more details at the national level, *see* Korean OECD, *supra* note 20, at 139; India, *see id* at 117; Italy, *see id* at 129; Lithuania, *see id* at 152; Chinese Taipei, *see id* at 192-193; Switzerland, *see* Summary of the Workshop on Cartel Screening in the Digital Era 6 (2018). For Brazil, *see Non-price Effects of Mergers - Note by Brazil* (2018); and for Mexico, *see* David Imhof, et el., *Screening for Bid-Rigging: Does It Work?* 5 (2017).

[24] Whether they adopt a technique of supervised learning, unsupervised learning, semi-supervised learning, or reinforcement learning. For insights about their differences, *see* R. Sathya & Annamma Abraham, *Comparison of Supervised and Unsupervised Learning Algorithms for Pattern Classification*, 2 INT. J. ADV. RES. ARTIFICIAL INTELL. 34 (2013). *See* also Delipetrev, *supra* note 11, at 6. Stefan Hunt, *From Maps to Apps: the Power of Machine Learning and Artificial Intelligence for Regulators*, Beesley Lecture Series on Regulatory Economics 6 (Oct. 19, 2017) (explaining that "much of what regulators do is ultimately about recognising patterns in the data," and that supervised machine learning, sometimes better than econometrics, can help find these patterns efficiently). Discussing one of the limits of machine learning, *see* Battista Biggio & Fabio Roli, *Wild Patterns: Ten Years After the Rise of Adversarial Machine Learning*, 84 PATTERN RECOGNIT. 317 (2018) (explaining how "adversarial input perturbations carefully crafted either at training or at test time can easily subvert" learning-based pattern classifiers such as deep networks). In future years, one should expect to find some companies using these adversarial techniques to mislead antitrust agencies' machine learning investigative tools.

[25] Explaining Natural Language Processing, *see* Robert Dale, *Industry WatchLaw and Word Order: NLP in Legal Tech* 25 NAT. LANG. ENG. 211 (2018). In the context of antitrust, *see* Suzanne Rab, *Artificial Intelligence, Algorithms and Antitrust* 18 COMPETITION L.J. 141, 142 (2019). Explaining Natural Language Understanding in the context of antitrust, *see* Jonathan Grudin, *From Tool to Partner: The Evolution of Human-Computer Interaction* § 7.5 (2017). In practice, the Federal Trade Commission is using a computational tool called Relativity, thanks to which it can search automatically for the substitutes of specific keywords. For more information, *see* RelativityOne, *Analytics Overview*, RelativityOne, https://help.relativity.com/RelativityOne/Content/Relativity/Analytics/Analytics.htm, archived at https://perma.cc/RP5U-Y38H.

[26] Marcela Mattiuzzo, *Algorithms and Big Data: Considerations on Algorithmic Governance and Its Consequences For Antitrust Analysis*, REV. DE ECON. CONTEMP., Jan. 2019, at 1, 14 (explaining that algorithms used by companies could be audited by agencies using sophisticated tools). Also, Wolfgang Alschner, *Sense and Similarity: Automating Legal Text Comparison*, *in* COMPUTATIONAL LEGAL STUDIES: THE PROMISE AND CHALLENGE OF DATA-DRIVEN RESEARCH 9 (Ryan Whalen ed., 2020) (explaining how pattern recognition works with large legal corpora). Also, Rob Nicholls, *Regtech as an Antitrust Enforcement Tool*, J. ANTITRUST ENFORC. 12 (2020) (suggesting that antitrust agencies could create a database of expected price distributions for certain products and use machine learning to detect deviations). Furthermore, *see* Schrepel, *supra* note 22, at 164 (explaining the need for antitrust agencies to analyze the coding of digital products). Lastly, *see* OECD, *supra* note 20, at 130 (underlining that market screenings are, for now, expensive).

[27] Discussing the rule of APIs in the context of data sharing, *see* Oscar Borgogno & Giuseppe Colangelo, *Data Sharing and Interoperability: Fostering Innovation and Competition Through APIs*, 35 COMPUT. LAW SECUR. REV. 1, 4 (2019). More generally, one could think of a system in which companies and agencies will share databases featuring a continuous and automatic addition of new (specified) data.

[28] Computational tools may help generate data about companies' behaviors (as living organisms), therefore allowing one to study them in action and increasing one's understanding of the ecology in which they evolve. The help of data scientists will prove crucial in the field. On the subject, *see* Makan Delrahim, *"Here I Go Again": New Developments for the Future of the Antitrust Division* 7 (2020) ("We've trained thousands of criminal investigators, certified fraud examiners, auditors, data scientists, and

agencies analyze documents. For example, these tools have allowed the European Commission to study 1.7 billion search queries for its investigation in the Google Shopping case.[29] In this respect, computational tools are bringing the "law time" closer to "market time."[30]

Besides, computational tools increase agencies' analytic capacities. They do so by allowing the comparison of large data sets across different periods and industries to detect anomalies.[31] These tools also enable agencies to integrate data from other agencies.[32] Much can be done to improve the cross-institutional use of data residing within different agencies from a same country. Similarly, the international dialogue between antitrust agencies, which is currently ensured by various networks such as the ICN, the OECD, and the ECN+, could be further automated.

Simultaneously, computational tools enable market players to conduct more thorough internal audits. In the future, one could imagine the design of new tools for assessing compliance with antitrust laws (almost instantaneously). It would require companies to compute the known parameters of any practice and assess the associated legal liability risk thanks to algorithms trained to antitrust laws. One could imagine that antitrust agencies will provide companies with their own computational tools to evaluate the risk even more accurately. These tools could improve over time using deep reinforcement learning models.[33]

B – Merger Control

Merger control differs from investigations of anticompetitive practices. As it turns out, these differences have implications for computational antitrust.

First, antitrust agencies must make a decision in all the concentrations notified to them. And they have a limited time to do so. As a result, the probability that agencies are making decisions under uncertainty is greater in merger control than in anticompetitive cases where they pick investigations that may go on for long

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procurement officials from nearly 500 federal, state, and local government agencies on recognizing collusion risks in the procurement process"). Also discussing the "Data Analytics Project" (using data for detecting wrongdoing) and "Collusion Analytics models that proactively identify red flags of antitrust crimes and related fraud schemes in bid and award data," *see Id*.

[29] Commission, *Antitrust: Commission Fines Google € 2.42 Billion for Abusing Dominance as Search Engine by Giving Illegal Advantage to Own Comparison Shopping Service*, European Commission (Jun. 27, 2017), https://ec.europa.eu/commission/presscorner/detail/en/IP_17_1784, archived at https://perma.cc/49UU-UTBU.

[30] *See* Richard Posner, *Antitrust in the New Economy*, 68 ANTITRUST L.J. 925, 939 (2001) (stressing, in 2001 already, how "troubling" was the "mismatch between law time and new-economy real time").

[31] The CMA calls that "predictive coding", *see* Simon Nichols, *Predictive Coding: How Technology Could Help to Streamline cases*, Gov.UK (July 24, 2020), https://competitionandmarkets.blog.gov.uk/2020/07/24/predictive-coding-how-technology-could-help-to-streamline-cases/, archived at https://perma.cc/GHL8-ZQLK (explaining that "predictive coding is a computer assisted process, programmed to search a company's electronic documents to find those that are relevant to the case").

[32] *See* Nicolas Petit, *Big Tech and the Digital Economy: The Moligopoly Scenario* 36-37 (2020) (showing how data in the hand of the U.S. Securities and Exchange Commission might enlighten antitrust law).

[33] *See* Abby Norman, *Researchers Develop a New Algorithm to Teach AI to Learn — and How to Adapt*, FUTURISM (Jul. 25, 2017), https://futurism.com/researchers-develop-a-new-algorithm-to-teach-ai-to-learn-and-how-to-adapt, archived at https://perma.cc/AP4J-PFZW (explaining that deep reinforcement algorithms work on their own by "trial and error" to achieve certain rewards); also Dom Galeon, *New Algorithm Lets AI Learn From Mistakes, Become a Little More Human*, FUTURISM (Mar. 2, 2018) https://futurism.com/ai-learn-mistakes-openai, archived at https://perma.cc/S2FS-KPBA (explaining the different techniques for training reinforcement algorithms, for example, giving them a cookie only when they reach the correct outcomes, or pushing them to look at their mistakes as potential successes).

periods. The more documents there are, the greater the uncertainty considering that agencies may face great complexity during the analytical process.[34] For example, the European Commission has examined over 2.7 million documents in the merger between Bayer and Monsanto.[35] The Department of Justice has been facing similar issues.[36] These difficulties in processing all the data (in the allotted time) is problematic considering that data are the backbone of merger analysis.[37] Computational antitrust could then prove helpful by providing agencies with the tools to *analyze extensive data sets* within the time constraint.[38]

Second, companies are very much in charge of the data being sent—as there are no injunctions to produce specific records, no dawn raids, and no discovery procedures (where applicable). It creates a first asymmetry between companies and agencies. For example, the European Commission underlined in *Dow/DuPont* that "the Parties did not mention their internal databases on crop protection patents and did not provide their competitive intelligence reports on competitors' crop protection patents in their responses to several initial Commission's requests for information."[39] This made the analysis more "difficult" than it should have been.[40] At times, this asymmetry even leads to questioning the integrity of the data. In the *WhatsApp* case, for instance, the Commission imposed a €110 million sanction on Facebook for providing misleading information.[41]

Once the agency has received the data, it processes it without sending it back to the companies.[42] That triggers a second asymmetry, thus making merger procedures more obscure than they could be. Computational antitrust could *fix* these *asymmetries* by introducing a systematized communication tool between companies and antitrust agencies. It could ensure that companies send (in real-time) agencies all information in specified databases and that firms get access to it

[34] Rupprecht Podszun & Sarah Langenstein, *Data as an Input in Competition Law Cases: Standards, Difficulties and Biases in EU Merger Control*, *in* LEGAL CHALLENGES OF BIG DATA (Cannataci, Falce & Pollicino eds., 2020) 174, 182 (2020). Also, Daniel A. Crane, *Rethinking Merger Efficiencies,* 110 MICH. L. REV. 347, 352 (2011) (explaining that "modem merger review requires predictions about the likely consequences of an event that has not yet occurred and that cannot be sampled, studied, or tested").
[35] Commission, *Mergers: Commission Clears Bayer's Acquisition of Monsanto, Subject to Conditions*, European Commission (March 21, 2018), https://ec.europa.eu/commission/presscorner/detail/en/IP_18_2282, archived at https://perma.cc/KAY5-A5T6?type=image.
[36] Delrahim, *supra* note 28, at 4 ("Increasingly, many transactions involve the acquisition of large troves of data. Understanding how that data may be used—and the potential competitive implications—is becoming more and more important in merger analysis").
[37] Albert A. Foer, *Prediction and Antitrust*, 56 ANTITRUST BULL. 505, 505 (2011) (underlining that "almost everything of importance about antitrust relates to the future"). Also, Thomas B. Leary, *The Inevitability of Uncertainty*, 3 COMPETITION L. INT'L 27 (2007) (stressing that "virtually all antitrust analysis involves predictions"). More generally, for a review of the literature encompassing legal judgment prediction, *see* Lance B. Eliot, *Legal Judgment Prediction (LJP): Amid the Advent of Autonomous AI Legal Reasoning* (2020).
[38] Also, OECD, *Algorithms and Collusion: Competition Policy in the Digital Age* 43 (2017) (underlining that "automated computer systems" may help "to organise and select relevant information").
[39] Commission Decision of 27.3.2017 Declaring a concentration to be compatible with the internal market and the EEA Agreement (Case M.7932 – Dow/DuPont) (C(2017) 1946) §97 (2017).
[40] *Id.* at §133.
[41] Commission, *Mergers: Commission fines Facebook €110 million for providing misleading information about WhatsApp takeover*, European Commission (May 18, 2017), https://ec.europa.eu/commission/presscorner/detail/en/IP_17_1369, archived at https://perma.cc/6XXC-SQ3S?type=image.
[42] Matthew Jennejohn, *Innovation and the Institutional Design of Merger Control*, 41 J. CORP. L. 167, 207 (2015).

once it has been processed.[43] Besides, one could use blockchain for creating immutable databases and ensure their integrity.[44]

Finally, one can imagine that computational tools will ultimately lead to more *dynamic* merger *analyses*.[45] Automated processing of big data is already allowing agencies to understand market power better. The first advances in computational antitrust have been made in that field starting in the mid-1990s thanks to simulation models' implementation.[46] They are used, for example, to measure product substitutability or efficiency claims.[47] Over time, computational methods will open new possibilities. One could think that they will allow companies and agencies to understand the competitive pressure between non-substitutable products, to quantify dynamic capabilities, and model pro-innovation policies.[48] Static variables will slowly make room for dynamic ones, if so desired.

C – Antitrust Policies

Computational methods will benefit the design, monitoring, and evaluation of antitrust policies. This will be achieved thanks to a combination of retroactive and predictive analyses.

First, computational techniques will improve retrospective of antitrust investigations, merger control decisions, and public policies. These retrospectives are notoriously challenging, and costly, to conduct. To be sure, antitrust agencies carry out high-level retrospective analyses in their annual activity reports, but these studies are mostly qualitative, and the level of aggregation is high.

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[43] The Assistant Attorney General Makan Delrahim called the use of new technologies "pivotal" for this reason, *see* Delrahim, *supra* note 28, at 5 ("the Division's new training initiative helps ensure that we are well-equipped to assess the competitive implications of the next transaction or course of conduct where these cutting-edge business technologies may be pivotal."). Also, *see* David Colarusso & Erika J. Rickard, *Speaking the Same Language: Data Standards and Disruptive Technologies in the Administration of Justice*, 50 SUFFOLK U. L. REV. 387, 404 (2017) (explaining that "the revolution will be standardized" thanks to new "tools to share information between court users and the courts").

[44] Schrepel, *supra* note 22, at 121-122 (explaining that all modifications to blockchain ledgers are visible, therefore making their manipulation or corruption knowable).

[45] *See*, for example, Ben Mermelstein, et al., *Internal versus External Growth in Industries with Scale Economies: A Computational Model of Optimal Merger Policy*, 128 J. POLIT. ECON. 301 (2019) (developing a computational model for merger policy in a dynamic setting in which investment plays a central role). Also, W. Brian Arthur, *Complexity Economics A Different Framework for Economic Thought, in* COMPLEXITY AND THE ECONOMY 2, 9-11 (W. Brian Arthur ed., 2015) (explaining that computation could be used to obtain general insights about how the world functions).

[46] Jonathan B. Baker, *Merger Simulation in an Administrative Context*, 77 ANTITRUST L.J. 451, 452 (2011) (arguing that merger simulation should be used for creating screening techniques or establishing presumptions). Also, Oliver Budzinski & Isabel Ruhmer, *Merger Simulation in Competition Policy: A Survey*, 6 J. COMPETITION LAW ECON. 277 (2009) (underlining that antitrust agencies have been using merger simulation models in horizontal mergers since the mid-1990s). Lastly, *see* Thomas Buettner, Giulio Federico & Szabolcs Lorincz, *The Use of Quantitative Economic Techniques in EU Merger Control*, 31 ANTITRUST 1 (2016) (explaining that, on top of simulation models, the European Commission has been using direct estimation methods).

[47] Computational tools could (partially) reconcile accuracy and predictability. Discussing the matter, *see* Jan Broulík, *Preventing Anticompetitive Conduct Directly and Indirectly: Accuracy Versus Predictability*, 64 ANTITRUST BULL. 115 (2019).

[48] *See* David J. Teece, Gary Pisano & Amy Shuen, *Dynamic Capabilities and Strategic Management*, 18 STRATEG. MANAG. J. 509 (1997). Also, *see* Sandro Claudio Leraa, Alex Pentland & Didier Sornette, *Prediction and Prevention of Disproportionally Dominant Agents in Complex Networks*, 117 PROC. NATL. ACAD. SCI. U.S.A. 27090, 27094 (2020) (developing a holistic model to address an industry' dynamism). Lastly, see Erik Brynjolfsson & Lorin M. Hitt, *Beyond Computation: Information Technology, Organizational Transformation and Business Performance*, 14 J. ECON. PERSPECT 23, 25 (2000) (explaining that the value of information technology is not "well captured by traditional macroeconomic measurement approaches," and stressing the need for developing a new methodology in response).

Recently, several agencies—including the Federal Trade Commission and the French antitrust agency[49]—have expressed their intention to conduct more targeted empirical studies for analyzing past merger decisions involving large digital firms.[50] Using a computational approach, agencies could carry out similar studies regarding their jurisprudence in which anticompetitive practices have been punished. After sanctions have been imposed, the (automatic) collection of market data could, for example, provide valuable information on their effectiveness, whether they are strictly monetary or also including structural and behavioral remedies.[51] They could also better estimate consumer savings thanks to their decisions and orient them accordingly.[52] Furthermore, antitrust agencies could systematically audit their processes to ensure they stay effective in a fast-changing technological environment.[53] Finally, they could carry out empirical studies of specific industries,[54] for example, to understand what conditions have allowed the emergence of new players when the market was deemed to have tipped.[55]

Second, computational antitrust will be *predictive*. Most of the laws passed in a majority of countries undergo a cost-benefit evaluation. The development of computational methods will help simulate the effects of new public policies and legislation, thus making the assessment more accurate while complying with what Jean Tirole called the requirement of "information-light" policies.[56] Although it is illusory to believe that one will soon attain a perfect simulation of reality, these methods will allow policymakers and regulators to be better informed.[57] Here again, both companies and agencies will benefit from computational antitrust deployment as long as one considers its limits (*see* below).

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[49] FTC, *Overview of the Merger Retrospective Program in the Bureau of Economics*, Federal Trade Commission, https://perma.cc/Q7BP-C2TP; OCDE, *Start-ups, Acquisitions Anticoncurrentielles et Seuils de Contrôle des Fusions – Contribution de la France* 4 (2020).

[50] These retroactive studies could lead to the creation of tools that are useful to the consumer. Discussing the subject, *see* Fabiana Di Porto & Mariateresa Maggiolino, *Algorithmic Information Disclosure by Regulators and Competition Authorities,* 19 GLOBAL JURIST 1, 2 (2019).

[51] William E. Kovacic, *Roads Not Taken: The Federal Trade Commission and Google,* CONCURRENTIALISTE (Mar. 9, 2020) www.leconcurrentialiste.com/william-kovacic-ftc-google/, archived at https://perma.cc/JK44-L2HC (stressing the need for the Federal Trade Commission to conduct retrospective studies regarding its investigation against Google). Also, Cary Coglianese & David Lehr, *Regulating by Robot: Administrative Decision Making in the Machine-Learning Era*, 105 GEO. L.J. 1147, 1218 (2017) (explaining that computational regulation will require agencies to engage in the quantitative coding of their decisions).

[52] Federal Trade Commission, *Agency Financial Report* 17 (2020) (estimating how many dollars are saved per consumer for every dollar spent by the agency in law enforcement).

[53] Alex 'Sandy' Pentland, *A Perspective on Legal Algorithms*, MIT COMPUTATIONAL LAW REPORT (December 6, 2019), https://law.mit.edu/pub/aperspectiveonlegalalgorithms, archived at https://perma.cc/2AVJ-LLGA.

[54] The Competition and Markets Authority, for example, has "conducted a detailed analysis of all of the [3-4 billion] search events seen by Google and Bing in a one-week period in the UK, in order to understand better the differences in the query data seen by these search engines," *see* CMA, *Online platforms and digital advertising* 93 (2020). This underscores the need to give antitrust agencies the power to require companies to send them data.

[55] Pinar Akman, *Competition Policy in a Globalized, Digitalized Economy* 10 (2019) (underlining the need for empirical research regarding digital markets). Also, discussing the "essential role of antitrust in tipped markets," *see* NICOLAS PETIT, BIG TECH AND THE DIGITAL ECONOMY: THE MOLIGOPOLY SCENARIO, 190 (2020); and *see* Mark A. Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CALIF. L. REV. 479, 497 (1998) (discussing tipping in the context of antitrust enforcement).

[56] Foer, *supra* note 37, at 522 (discussing the possibility of using predictive tools to anticipate the effects of a public decision over a period ranging from two to five years). Jean Tirole, *Market Failures and Public Policy*, 105 AM. ECON. REV 1665, 1666 (2015) (defining information-light policies as "policies that do not require information that is unlikely to be held by regulators")

[57] For a fictional take on it, *see* Alex Garland, *Devs* (2020) https://www.imdb.com/title/tt8134186, archived at https://perma.cc/A9HW-F4N4.

III. The Challenges of Computational Antitrust

Computational antitrust is coming. This simple observation does not mean that one should adopt a passive (some would say defeatist) attitude. On the contrary, several challenges deserve one's full attention. Some are common to (the use of) computational methods in all legal fields (**A**), while others are specific to computational antitrust (**B**). Eventually, they come down to human issues rather than technological ones (**C**).

A – General Challenges to Computational Law

In the coming years, computational law will be the subject of a growing number of fantasies and criticisms. The further computational law will infiltrate our institutions, the greater those fantasies and criticisms will become.[58]

Often, the careful observer will find the concept of control at the heart of these reactions. Those who believe computers can do better than humans in all matters have been utterly enthusiastic about transferring control from humans to machines. The opposite is also true; algorithms and AI have been described as a "black box" to denounce their supposedly obscure decision-making processes.[59]

Transparency will be the referee—showing the nuts and bolts, stressing the possibilities, the limits, and actual functioning of computational antitrust. Of course, not all the data used and generated by computational tools should be publicly available, but perhaps processes and mechanisms should be. Contrary to human decision-making, one can reveal the working of computational decision-making.[60] In other words, the process of computation does not have to be a black box. Human reasoning is "noisy," but computation does not have to be;[61] after all, computational tools are what we decide to build. If transparency is an important value, one can design computational tools that emphasize it.

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[58] For example, artificial intelligence will allow the automation of many tasks, *see* Harry Surden, *Machine Learning and Law*, 89 WASH. L. REV. 87, 88 (2014) ("there may be a limited, but not insignificant, subset of legal tasks that are capable of being partially automated using current AI techniques despite their limitations relative to human cognition"). One could also seek to simplify search, grant easier document access, provide better document analysis, send automatic court or agencies' updates, and give API access to court filings, *see* Michelle Hook Dewey & G. Patrick Flanagan, *Litigation Analytics: Bringing Experience to New Tools*, 23 AALL SPECTRUM 41, 42-43 (2019).

[59] Leo Breiman, *Statistical Modeling: The Two Cultures,* 16 STAT. SCI. 199, 199 (2001) (describing algorithmic modeling as a "black box" for the first-time). On the contrary, *see* Cary Coglianese & David Lehr, *Transparency and Algorithmic Governance*, 71 ADMIN. L. REV. 1, 21 (2019) (explaining that the use of algorithms does not necessarily engender a "black-boxed" government, but could also increase "public's ability to peer inside government and acquire information about what officials are doing").

[60] *See* Coglianese & Lehr, *supra* note 51, at 1214 (explaining that machine-learning algorithms are directed toward objectives decided by humans). Even when the machines will define the objectives themselves, their decision-making process could be made transparent—if designed to this end.

[61] Daniel Kahneman, *Artificial Intelligence and Behavioural Economics: Comment*, *in* THE ECONOMICS OF ARTIFICIAL INTELLIGENCE 587, 610 (Ajay Agrawal, et al. 2019) (explaining that, because computers are not noisy, they are "better at statistical reasoning" than humans. According to the author, the consequence should be to "replace humans by algorithms whenever possible"). Also, *see* Mary-Anne Williams, *Robot Social Intelligence* 48 (2012) (underlining that "[r]obots and people need cognitive skills to explain and predict each others' behaviour"). Furthermore, Mark A. Lemley & Bryan Casey, *Remedies for Robots*, 86 U. CHI. L. REV. 1311, 1365 (2019) (explaining that although "[t]ransparency is a desirable goal in the abstract. (...) We may be able to find out what an AI system did. But, increasingly, we may not be able to understand why it did what it did"). Interestingly, understanding the "why" behind AI decision-making might be possible thanks to AI. For example, GPT-3 can be used for translating code into plain English, *see* Jason Morris, *Computational Law Diary: What does GPT-3 Mean for Rules as Code?*, Round Table Law MEDIUM (July 17, 2020), archived at https://perma.cc/4UX6-JUFM.

In fact, transparency could ensure that computational approaches maximize two objectives: (i) maintaining and (ii) improving our legal systems. The first is about guaranteeing the many human rights currently recognized and enforced.[62] Computational tools must not put them at risk. For example, procedural fairness ought to be maintained despite the use of sophisticated tools by one party only.[63] One will have to define a new framework for the admissibility of the evidence produced by these tools. Indeed, computational tools should not lead to the production of evidence whose creation process cannot be verified. Karl Popper's work will be valuable in this regard.[64]

The second item relates to using computational methods for ensuring the effectiveness of different rights that are still being disregarded (in practice) or denied. For example, legal scholars have been documenting discriminatory court decisions and legislation.[65] If the decision-making becomes transparent, and if the data is duly secured using an architecture designed for the purpose, computational tools will be positioned to reduce these unfortunate outcomes. Indeed, one will be able to identify when and how human rights have been infringed[66] and assign liability on that basis.[67] For these reasons, transparency seems to be a prerequisite for the broad adoption of computational tools.[68]

B – Challenges Specific to Computational Antitrust

Computational antitrust is also facing specific challenges. The first relates to developing the right *tools*. It implies coding antitrust laws and rulings to create efficient methods for (consistently) assessing compliance with them. It also implies helping agencies to automate enforcement and merger control procedures. Subsequently, one will be required to engage in the actual development of these tools and test which ones are most adapted to automating different parts of antitrust law. This testing is one of computational antitrust top priorities—it should lead to rapid results.

The second is tied to *data*, and, in the end, to their *scope*. To identify which data (and data structures) companies and agencies will need to feed the above tools, one

[62] *See* Delipetrev, *supra* note 11, at 21 (identifying four ethical principles: (i) respect for human autonomy, (ii) prevention of harm, (iii) fairness, (iv) explainability).
[63] Bonin & Malhi, *supra* note 23, at 471 (underlining that legal procedures in European law must comply with the Charter of Fundamental Rights of the European Union and the principle of "equality of arms").
[64] *See*, in particular, KARL POPPER, CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE (2002).
[65] *See* Jonathan P. Kastellec, *Racial Diversity and Judicial Influence on Appellate Courts*, 57 AM. J. POL. SC. 167, 169 (2012) (exploring different empirical studies documenting the differences in judicial voting across groups). Also, *see* Christina L. Boyd, *Representation on the Courts?: The Effects of Trial Judges' Sex and Race*, 69 POL. RES. Q. 788, 788 (2016) (showing that "trial judge's sex and race have very large effects on his or her decision making"), and David S. Abrams, Marianne Bertrand & Sendhil Mullainathan, *Do Judges Vary in Their Treatment of Race*, 41 J. LEGAL STUD. 347, 350 (2012). Outside of the United States, *see* Nienke Grossman, *Sex on the Bench: Do Women Judges Matter to the Legitimacy of International Courts*, 12 CHI. J. INT'L L. 647 (2012).
[66] Giovanni De Gregorio & Sofia Ranchordás, *Breaking Down Information Silos with Big Data: A Legal Analysis of Data Sharing* 214, *in* LEGAL CHALLENGES OF BIG DATA (Cannataci, Falce & Pollicino eds., 2020) (underlining that "the creation of a centralized form of data storage and sharing could put at stake the privacy of citizens"). Also, discussing why (big) data controllers could be held liable, *see id*. 224.
[67] Coglianese & Lehr, *supra* note 51, at 1223 (2017).
[68] This goes further than providing access to the information that results from these mechanisms. On the subject, the First and Fourth Amendments already oblige the U.S. government to provide open access to the information it is creating (using computational tools or not). This implies making the processing transparent. Making it obscure would be a missed opportunity.

will be required to address the objective(s) of computational antitrust. It appears that the use of computational tools for retrospective analysis and the making of counterfactuals is a logical application[69] while predictive analysis is more debatable in the field of antitrust.

To be sure, our ability to measure variables is increasing over the decades. Patterns are discernible, and regularities can be deduced from a real-world phenomenon, making it increasingly possible to use predictive tools to measure the effects of antitrust laws, decisions, and related policies over specific variables (translating the objective(s) of antitrust agencies).[70]

That being said, computational tools (as others) are poorly suited for predicting all the forces in the economy.[71] They do not lead to a "theory of everything."[72] Quantum computing will help to integrate more variables. Combined with AI systems, quantum computers will better identify the reasons for economic growth. And yet, one should not be under the impression that it will be possible to capture the entire world around us in a computer program—at least, not anytime soon.[73] On that basis, one should doubt whether computational antitrust could justify *ex-ante* regulations and other market design objectives.[74] In fact, one could even argue that, by allowing a faster and more accurate enforcement of antitrust laws, computational tools will reduce the need for *ex-ante* regulations. In this sense, perhaps the curious task of computational antitrust will be "to demonstrate to men how little they really know about what they imagine they can design."[75]

The third is tied to the *role* one should give computational tools in decision-making processes (that is, where they are used). One will want to discuss the extent to which they could justify decisions on their own, including their probative force in anticompetitive investigations and mergers.[76] It will require hiring the personnel for designing and exploiting them as they will not get to the right answers by themselves. [77] It will also require discussing the (comparative) importance of non-

[69] *See* William M. Landes & Richard A. Posner, *Market Power in Antitrust Cases*, 94 HARV. L. REV. 937, 982 (1981) (developing a price prediction model for counterfactuals).
[70] Di Porto & Maggiolino, *supra* note 50, at 7 (defending the idea of testing remedies before implementing them).
[71] If only because unexpected elements cannot be computed in advance, *see* NASSIM NICHOLAS TALEB, THE BLACK SWAN: THE IMPACT OF THE HIGHLY IMPROBABLE 1-10 (2d ed. 2010) (explaining that inductive reasoning does not allow to tackle the be never-before-seen events—described as "Black Swans").
[72] Arthur, *supra* note 4, at 9 (showing how computer experiments can be used for isolating economic phenomena). Discussing the limits, *see* JOSEPH A. SCHUMPETER, HISTORY OF ECONOMIC ANALYSIS 241 (1954, ed. 2006) (explaining that one can establish "certain theorems" around the economic life of our societies, "but we can never observe them all"). Similarly, Hayek, *supra* note 15, at 66 (stressing that one cannot grasp the whole complex phenomenon, but some patterns only).
[73] For this reason, computational analyses are complemented with other ones curated by the European Commission, *see* Buettner, et al., *supra* note 46, at 20. It will be interesting to analyze the extent to which computational tools will also improve in qualitative terms. For a long-term perspective, *see* Kahneman, *supra* note 61, at 610 ("I do not think that there is very much that we can do that computers will not eventually be programmed to do").
[74] *See* Landes & Posner, *supra* note 69, at 982 (developing a price prediction model for counterfactuals).
[75] Hayek assigned this "curious task" to economics, *see* FRIEDRICH AUGUST VON HAYEK, ET AL., THE COLLECTED WORKS OF F. A. HAYEK 76 (1989).
[76] Daniel A. Crane, *Rules versus Standards in Antitrust Adjudication*, 64 WASH. & LEE L. REV. 49, 86 (2007) (arguing that predictive analyses are not sufficient to justify antitrust rules). Foer, *supra* note 37, at 522 (underlining that "[i]n addition to predicting, the tools of prediction might be aimed at better understanding the present").
[77] Some of these tools will require to be fed with adequate data. Others will need to be set up within the agency's own ecosystem. When agencies do not design them (but, for example, borrow them from another agency), issues will arise regarding the integration of these tools into their existing networks.

computable elements.[78] In reaction to antitrust 2.0, part of the doctrine had rightly underlined the need to consider more than quantifiable factors.[79] We must not fall into the same trap while constructing antitrust 3.0.[80]

C – In the End: A Human Question

Eventually, technical questions will get technical answers. The most critical challenge for developing computational antitrust is related to the interaction between our legal systems and technical tools. This is a human challenge. As one author put it in 1962, "we must bear in mind that it is not machines that have changed the lives of men, but the adaptations that men themselves have adopted in response to machines. It is not the invention of tools, however subtle, complex, or powerful, that constitutes man's greatest achievement, but the ability to use the tools that man has developed within himself."[81]

Providing this challenge a satisfying answer will require West Coast Code and East Coast Code to cooperate.[82] This collaboration requires coders (computer scientists, data scientists, developers) and the antitrust community (companies, policymakers, regulators) to prepare their respective fields so computational antitrust can thrive. Coders will be required to devote their time to developing the recipes—the programming of sequences of specific instructions to achieve a specific result. Companies and agencies will provide the ingredients—which requires identifying the ones needed and how to get them (i.e., how to transform data into information). In the end, these recipes and ingredients will complement each other; the nature of one will change the nature of the other.

Institutional changes will facilitate the cooperation of these two communities. Several actions are required in this regard. First, one will be required to create proper incentives for computational antitrust development. On the side of coders, computer scientists, and data scientists, this implies the creation of different reward systems to ensure they get (and stay) involved in the field. On the side of companies and agencies, this requires enlarging the teams dedicated to these subjects and giving them appropriate means.[83] Second, one will have to establish the conditions

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[78] Salil K. Mehra, *Antitrust and the Robo-Seller: Competition in the Time of Algorithms*, 100 MINN. L. REV. 1232, 1373 (2015) (underlining that we ought to "avoid making the perfect the enemy of the good in an area undergoing such rapid and uncertain change," indeed, "cooperatively generating norms and best practices" may help enforcing antitrust in digital markets).

[79] *See* Eleanor M. Fox, *Modernization of Antitrust: A New Equilibrium*, 66 CORNELL L. REV. 1140, 1140 (1980-19081) (proposing "a formulation for achieving a new equilibrium designed to advance the efficiency goals and harmonize the non-efficiency goals").

[80] George A. Akerlof, *Sins of Omission and the Practice of Economic*, 58 J. ECON. LIT. 405, 406 (2020) (explaining that economic research is ignoring "important topics and problems that are difficult to approach in a hard way," which, by analogy, could be transposed to antitrust 3.0).

[81] Lee Loevinger, *Jurimetrics: Science and Prediction in the Field of Law*, 3 M.U.L.L. MOD. USES LOG. L. 187, 205 (1962).

[82] Lawrence Lessig, *The Code Is the Law*, TECH INSIDER (April 9, 1999), https://tech-insider.org/berkman-center/research/1999/0409.html, archived at https://perma.cc/P9KV-DDX8 (calling West Coast Code the one coming from the Valley, and East Coast Code the one coming from Congress); also, LAWRENCE LESSIG, CODE: VERSION 2.0 72 (2006) (explaining that, over time, "[t]he power of East Coast Code over West Coast Code has increased").

[83] According to Matthew Newman, Margrethe Vestager confirmed the European Commission is increasing its computing power to process large amounts of data in merger and antitrust cases, *see* Matthew Newman, *Online Pricing Algorithms Prompt EU Antitrust Regulator to Boost Detection Tools*, MLEX (Sept. 24, 2018). On top of financial means, developing computational antitrust also requires giving these

for sustained collaboration between companies and agencies. Computational antitrust should not become a zero-sum game in which the gains made by companies or agencies systematically penalize the other. One must question the creation of safe harbors, new procedural rules, and, overall, a less confrontational approach between the different stakeholders. They will cooperate if they have a vested interest in doing so.[84] Of course, achieving such cooperation will be difficult; Justice Holmes's "bad man" will not disappear.[85] But it is possible.

teams access to the entire decision-making process, rather than simply involving them at the beginning and the end of it.

[84] Discussing such a system, *see* Anthony J. Casey & Anthony Niblett, *The Death of Rules and Standards*, 92 IND. L.J. 1401, 1411 (2017) (underlining the possibility to create "microdirectives" for regulating individuals and companies by sending them appropriate legal information). One could also imagine that different legal obligations could be put on companies, *see* Di Porto & Maggiolino, *supra* note 50, at 7 (arguing for the creation of tailored regulation, for example, when it comes to disclosure). Lastly, *see* Thorsten Kaeseberg, *The Code-ification of Law and Its Potential Effects*, 20 COMPUT. L. REV. INT. 107, 238 (2019) (underlining that "[w]hether we call it algorithmic, adaptive, personalized, granular, or simply digital law—there will be an increasing trend towards granularization, which will affect the legislature, executive branch and judiciary").

[85] Holmes, *supra* note 17.