# INTERNATIONAL JOURNAL FOR LEGAL RESEARCH AND ANALYSIS

Open Access, Refereed Journal Multi Disciplinary
Peer Reviewed

www.ijlra.com

 ISSN: 2582-6433

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 ISSN: 2582-6433

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 ISSN: 2582-6433

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 ISSN: 2582-6433

# ALGORITHMIC COLLUSION AND ITS CHALLENGES TO ANTITRUST REGULATIONS

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## *Abstract*

The rise of algorithmic collusion, driven by artificial intelligence (AI) and machine learning, poses significant challenges to traditional antitrust and competition law frameworks. As firms increasingly deploy self-learning algorithms to optimize pricing strategies, markets risk being distorted through autonomous, collusive behaviours without explicit human coordination. This paper explores the mechanisms of algorithmic collusion, distinguishing between explicit and tacit collusion, and examines the inadequacies of existing antitrust regulations in addressing these complex dynamics. It delves into global regulatory responses, including the European Union's Digital Markets Act and proposed reforms in India through the Draft Digital Competition Bill, 2024. The paper argues for a multifaceted approach to regulation, combining ex-ante algorithm audits, enhanced investigatory powers, and international cooperation to mitigate the risks of algorithmic coordination. By analysing key legal concepts such as intent, liability, and market effects, the research highlights the need for adaptive, technology-informed regulatory frameworks to preserve competitive fairness and consumer welfare in rapidly evolving digital markets.

***Keywords:*** *Algorithmic Collusion, Competition Law, Antitrust Regulation, Artificial Intelligence, Machine Learning, Tacit Collusion, Digital Markets, Ex-Ante Regulation, Consumer Welfare.*

## Introduction

The integration of artificial intelligence (AI) and machine learning into commercial decision-making processes has fundamentally reshaped market competition. Algorithms now influence pricing strategies, optimize supply chains, and enhance consumer targeting. While these innovations can increase efficiency and improve consumer welfare, they also introduce the risk of collusion — a phenomenon where firms coordinate to manipulate market outcomes, leading to higher prices, reduced innovation, and consumer harm. As firms increasingly rely on complex pricing algorithms, regulators and scholars alike have raised concerns about the

 ISSN: 2582-6433

potential for algorithmic collusion, a challenge that existing competition laws struggle to address.

Algorithmic collusion occurs when firms use algorithms to coordinate pricing or other market behaviours, either explicitly through programmed instructions or tacitly through adaptive learning processes. In explicit algorithmic collusion, firms might intentionally design algorithms to communicate or signal pricing strategies, akin to traditional cartel behaviour. In contrast, tacit collusion can emerge when algorithms independently learn to optimize profits through continuous market interaction, detecting patterns in competitors' pricing and adjusting accordingly without human intervention. This latter form of collusion is particularly problematic, as it challenges core legal concepts such as intent and agreement, which are central to traditional antitrust enforcement.

The mechanisms of algorithmic collusion vary in complexity but typically involve rapid, data-driven decision-making processes. Algorithms can monitor competitors' prices in real time, detect deviations from a coordinated price point, and respond instantly to punish non-cooperative behaviour — replicating the dynamics of human cartels but at a speed and precision impossible for human actors. For example, in online marketplaces, firms may use dynamic pricing algorithms that automatically match competitors' prices, sustaining high price levels across the market without explicit coordination. In these scenarios, the collusive outcome arises not from direct human intent but from the algorithm's optimization logic, raising difficult questions about liability and enforcement.

These algorithmic practices pose a unique challenge to competition law, which was developed to regulate human-driven market behaviours. Antitrust frameworks, such as the Sherman Act in the United States or Article 101 of the Treaty on the Functioning of the European Union (TFEU), are designed to address explicit agreements and intentional collusion. While regulators in jurisdictions like the European Union (EU) and the United States (US) are actively evolving their frameworks to address this issue, India's approach to regulating algorithmic collusion is still emerging.

However, in cases of tacit algorithmic collusion, there may be no discernible agreement or intent, making it difficult to establish legal culpability under current laws. Additionally, the global reach of digital markets complicates enforcement, as algorithms operate across multiple

 ISSN: 2582-6433

jurisdictions, often beyond the immediate oversight of national regulators.

Given these complexities, this paper seeks to explore the research question: How do algorithmic practices challenge traditional competition law, and what regulatory adaptations might be necessary? It also analyses whether the Competition Act, 2002 is well equipped to scrutinize algorithmic collusion, specifically algorithms with the logic to collude and self-learning algorithms.

## Understanding Algorithmic Collusion

Algorithmic collusion refers to the phenomenon where firms use algorithms, particularly pricing algorithms, to coordinate strategies and sustain supra-competitive prices, either intentionally or as an unintended consequence of algorithmic optimization. This phenomenon has raised significant concerns in competition law, as it challenges traditional antitrust enforcement mechanisms, which are primarily designed to address human-driven collusion (Ezrachi & Stucke, 2016)[1]. To fully grasp the implications of algorithmic collusion, it is essential to understand its mechanisms, the role of artificial intelligence (AI), and the distinction between explicit and tacit collusion.

Collusion typically occurs when firms agree to restrict competition, often by fixing prices, limiting output, or dividing markets. Algorithms, however, can facilitate collusion in more sophisticated and dynamic ways. Calvano et al. (2020)[2] demonstrated through economic simulations that self-learning algorithms can autonomously learn to collude without human input. Their study showed that Q-learning algorithms, commonly used in reinforcement learning, can identify profit-maximizing strategies by observing market reactions, gradually converging on collusive pricing structures.

Ezrachi and Stucke (2016)[3] categorize algorithmic collusion into four main types:

1. Messenger Collusion: Algorithms are deliberately programmed to exchange pricing signals or coordinate strategies.

[1] 'Artificial Intelligence & Collusion: When Computers Inhibit Competition by Ariel Ezrachi, Maurice E. Stucke :: SSRN' <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2591874> accessed 8 March 2025.
[2] 'Artificial Intelligence, Algorithmic Pricing and Collusion by Emilio Calvano, Giacomo Calzolari, Vincenzo Denicolò, Sergio Pastorello :: SSRN' <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3304991> accessed 8 March 2025.
[3] Ibid.

 ISSN: 2582-6433

2. Hub-and-Spoke Collusion: A common algorithm, often provided by a third-party vendor, coordinates prices across multiple firms, acting as a "hub" for price-setting.
3. Predictable Agent Collusion: Algorithms learn to anticipate and respond to competitors' pricing decisions, leading to tacitly coordinated outcomes.
4. Autonomous Machine Collusion: Self-learning algorithms independently discover collusive strategies through trial and error, even without direct programming for collusion.

These mechanisms illustrate that collusion is not limited to explicit agreements. Algorithms can detect and punish price deviations at lightning speed, sustaining collusion with unprecedented stability (Harrington, 2018)[4].

AI-driven pricing algorithms are particularly concerning because of their adaptability and complexity. Machine learning models can analyse vast amounts of market data, learn competitive patterns, and adjust pricing strategies in real time. While firms may adopt these algorithms to optimize individual performance, the collective effect of multiple firms using similar algorithms can unintentionally lead to collusion (Gal, 2019)[5]. This raises important questions about liability — if collusion emerges as a byproduct of algorithmic optimization, should firms be held accountable for anti-competitive outcomes they did not explicitly intend? Scholars like Gal and Elkin-Koren (2016)[6] argue that the opacity of AI decision-making further complicates regulatory efforts. Algorithms operate as "black boxes," meaning that even the developers themselves may not fully understand the decision-making logic. This lack of transparency makes it difficult for regulators to prove collusion or demonstrate intent, a critical element in antitrust cases.

A critical aspect of algorithmic collusion is the distinction between explicit and tacit collusion. Explicit collusion, where firms deliberately agree to restrict competition, is relatively straightforward to prosecute under traditional competition law frameworks. However, tacit collusion — where firms align their strategies without explicit communication — presents a more significant challenge.

[4] Joseph E Harrington, 'DEVELOPING COMPETITION LAW FOR COLLUSION BY AUTONOMOUS ARTIFICIAL AGENTS†' (2018) 14 Journal of Competition Law & Economics 331 <https://academic.oup.com/jcle/article/14/3/331/5292366> accessed 8 March 2025.
[5] Michal Gal, 'Algorithms as Illegal Agreements' (Social Science Research Network, 2 May 2018) <https://papers.ssrn.com/abstract=3171977> accessed 8 March 2025.
[6] Michal Gal and Niva Elkin-Koren, 'Algorithmic Consumers' (Social Science Research Network, 8 August 2016) <https://papers.ssrn.com/abstract=2876201> accessed 8 March 2025.

 ISSN: 2582-6433

Calvano et al. (2020) showed that algorithms, through repeated interactions, can reach equilibrium prices that resemble cartel behaviour, even in the absence of direct communication. This aligns with the economic theory of conscious parallelism, where firms independently mimic competitors' strategies to maintain higher prices. While conscious parallelism is generally not illegal, the speed and precision of algorithmic coordination blur the line between lawful market adaptation and unlawful collusion.

Ezrachi and Stucke (2017) warn that tacit algorithmic collusion could become more prevalent as AI systems become more sophisticated. They argue that antitrust authorities may need to rethink core legal concepts like "agreement" and consider alternative regulatory strategies, such as ex-ante algorithmic audits or stricter oversight of high-risk markets.

## Legal and Regulatory Challenges

The rise of algorithmic pricing and artificial intelligence (AI) in market strategies has transformed competition dynamics, posing new challenges to antitrust enforcement. While algorithms can optimize pricing and enhance market efficiency, they can also facilitate collusion, raising concerns about consumer harm and market distortion. Scholars like have explored the mechanisms through which algorithms can align prices and sustain collusive outcomes, even without explicit human coordination. These new forms of algorithmic collusion challenge the foundations of competition law, particularly around issues of intent, liability, and jurisdiction.

Traditional competition law is designed to address human-driven collusion, often relying on evidence of communication or explicit agreements between competitors. For example, Section 3 and 4 of Competition Act, 2002, Article 101 of the Treaty on the Functioning of the European Union (TFEU) and the Sherman Act in the United States prohibit cartels and price-fixing arrangements based on the existence of an “agreement” or “concerted practice.” However, algorithms can learn to collude autonomously, creating collusive outcomes without direct human input or communication.

The rapid integration of artificial intelligence (AI) and machine learning into market strategies has introduced significant regulatory challenges for competition law in India. As firms increasingly rely on algorithms for pricing and decision-making, the risk of algorithmic collusion — where algorithms autonomously coordinate market outcomes — has emerged as

 ISSN: 2582-6433

a critical concern. India's competition framework, primarily governed by the Competition Act, 2002, faces limitations in addressing the complexities of algorithm-driven collusion, especially in scenarios where coordination occurs without explicit human intent or communication.

One of the fundamental challenges lies in the nature of India's existing legal framework. Section 3 of the Competition Act prohibits anti-competitive agreements, including cartels and price-fixing arrangements. However, these provisions are predicated on the existence of an "agreement" or "concerted practice" — concepts that become difficult to establish in cases of tacit algorithmic collusion. When algorithms learn to collude independently through repeated interactions, stabilizing prices without direct human intervention, proving an agreement becomes a near-impossible task under current legal standards.

Furthermore, the requirement to demonstrate intent or knowledge adds another layer of complexity. Traditional competition law assumes that collusion arises from deliberate human action, but algorithms can achieve collusive outcomes through autonomous optimization processes. This raises difficult questions: Can firms be held liable for unintended collusive behaviour if it emerges purely as a byproduct of algorithmic logic? Should companies be responsible for continuously auditing their algorithms to prevent potential collusion?
India's regulatory apparatus also grapples with resource and expertise limitations. The Competition Commission of India (CCI), while proactive in addressing evolving market dynamics, may lack the technical capacity to dissect complex algorithmic systems. Investigating algorithmic collusion would require not only legal expertise but also sophisticated data analysis tools, AI specialists, and the ability to trace algorithmic decision-making processes — a challenge compounded by the "black box" nature of many machine learning models.

Recognizing these gaps, India has begun exploring ways to modernize its competition framework. The Draft Digital Competition Bill, 2024, proposes key reforms to strengthen regulatory oversight over digital markets. Notable provisions include ex-ante regulation for dominant digital platforms, mandatory algorithmic transparency requirements, and enhanced investigatory powers for the CCI. If implemented effectively, these measures could give regulators the authority to conduct algorithm audits, monitor pricing anomalies, and intervene before collusive practices harm market competition.

 ISSN: 2582-6433

However, successful enforcement will hinge on practical implementation. The CCI would need to build technical expertise, collaborate with tech firms and academic researchers, and invest in AI-driven monitoring tools capable of detecting algorithmic collusion in real time. International cooperation will also be essential, given that algorithms operate across borders, making unilateral enforcement less effective in the face of globally interconnected digital markets.

Calvano et al. (2020) demonstrated through simulations that Q-learning algorithms, commonly used in reinforcement learning, can independently discover profit-maximizing strategies by repeatedly interacting in a simulated market. These algorithms gradually learn to avoid price wars, stabilizing at higher prices — behaviour that mirrors cartel-like outcomes but without explicit coordination. Because current competition laws hinge on proving an "agreement," regulators struggle to address algorithmic collusion when the algorithms themselves, rather than human actors, are driving the anti-competitive outcomes.

Gal and Elkin-Koren (2017) argue that existing legal tools may be inadequate to address these algorithmic realities, as they were designed for a pre-digital market. They advocate for a shift in legal thinking, suggesting that regulators may need to move toward a "market effect" standard, where the focus is on the anti-competitive impact rather than the existence of a formal agreement.

A major complication in regulating algorithmic collusion is determining intent and liability. In human-driven cartels, liability is relatively straightforward: firms deliberately engage in anti-competitive practices. But with algorithmic systems, collusion can emerge as an unintended consequence of optimization processes. The question then becomes: can firms be held liable for collusion facilitated by algorithms, even in the absence of direct human intent?
Ezrachi and Stucke (2016) argue that firms should bear responsibility for the behaviour of their algorithms, especially if they knowingly deploy algorithms capable of learning collusive strategies. They suggest that firms could be held liable under the doctrine of reckless disregard, where negligence in monitoring algorithmic behaviour could be treated as tacit approval of collusive practices.

However, the challenge lies in proving culpability. Harrington (2018) notes that even when firms claim ignorance of their algorithms' behaviour, the very act of using self-learning systems

 ISSN: 2582-6433

in sensitive markets may imply a degree of responsibility. This tension raises critical policy questions: should firms be required to conduct regular audits of their algorithms? Should regulators mandate algorithmic transparency to detect collusive tendencies?

The lack of legal clarity around intent in algorithmic collusion cases creates a regulatory blind spot, potentially allowing firms to shield themselves from liability by blaming unintended algorithmic outcomes.

The inherently global nature of digital markets further complicates regulatory enforcement. Algorithms operate in real time across multiple jurisdictions, making it difficult for national competition authorities to monitor, investigate, and prosecute cross-border collusion. For instance, an algorithm developed by a U.S. firm could interact with algorithms deployed by firms in Europe and Asia, creating a complex web of international interactions that no single regulator can fully oversee.

Competition authorities face limitations in their investigatory powers when collusion spans multiple countries, and differing legal standards across jurisdictions further hinder coordinated enforcement efforts. For example, the EU's competition law framework may approach algorithmic collusion differently from U.S. antitrust law, leading to inconsistent outcomes and fragmented enforcement.

One potential solution, as proposed by Gal and Elkin-Koren (2017), is increased global cooperation through international competition networks. Regulators could share data, pool resources, and develop common standards for monitoring algorithmic pricing, reducing the risk of jurisdictional arbitrage.

One of the core debates in regulating algorithmic collusion is whether authorities should intervene proactively (before harm occurs) or reactively (after collusion has been detected). Mehra (2016)[7] argues that traditional ex-post enforcement — where regulators investigate and sanction firms after collusive behaviour is identified — may be inadequate in algorithm-driven markets, given the speed and complexity of algorithmic decision-making. By the time authorities detect and investigate collusion, consumers may have already suffered prolonged harm.

[7] Salil K Mehra, 'Antitrust and the Robo-Seller: Competition in the Time of Algorithms' (Social Science Research Network, 10 March 2015) <https://papers.ssrn.com/abstract=2576341> accessed 8 March 2025.

 ISSN: 2582-6433

To mitigate this, some scholars advocate for ex-ante algorithm audits. Schwalbe (2018)[8] suggests that competition authorities could require firms to submit algorithms for pre-market approval, allowing regulators to test for collusive tendencies in controlled environments. This approach, while resource-intensive, could prevent harmful collusion before it distorts markets. However, Schwalbe acknowledges the practical difficulties: algorithms evolve through machine learning, meaning a non-collusive algorithm today could learn collusive strategies tomorrow.

In contrast, Hüschelrath and Laitenberger (2020)[9] argue that ex-post investigations remain essential, particularly for detecting emergent collusion that arises through real-world interactions. They propose enhancing current enforcement tools with algorithmic monitoring systems that continuously scan markets for signs of suspicious pricing patterns — a hybrid approach that combines elements of proactive and reactive regulation.

The policy response to algorithmic collusion has varied across jurisdictions, with some regions taking more aggressive stances than others. The European Union (EU) has been at the forefront of algorithmic regulation, with the Digital Markets Act (DMA) introducing stricter rules for dominant digital platforms. The European Commission has also signalled a willingness to treat algorithmic collusion as a serious antitrust violation, even in the absence of explicit agreements.

In the United States, regulatory efforts have been comparatively cautious, though this may be changing. Scholars highlights growing interest among U.S. antitrust authorities in addressing digital market power, with calls for expanded investigative capabilities and the creation of specialized tech-focused enforcement units. The Federal Trade Commission (FTC) has also begun exploring the competitive impact of algorithmic practices, signaling a potential shift toward more proactive oversight.

Meanwhile, Australia's Competition and Consumer Commission (ACCC) has proposed new digital market regulations, emphasizing the need for transparency in algorithmic pricing systems. This aligns with broader international trends, where regulators increasingly recognize

[8] Ulrich Schwalbe, 'Algorithms, Machine Learning, and Collusion' (Social Science Research Network, 1 June 2018) <https://papers.ssrn.com/abstract=3232631> accessed 8 March 2025.
[9] Matthias Hunold & Kai Hüschelrath & Ulrich Laitenberger & Johannes Muthers, 2020. "Competition, Collusion, and Spatial Sales Patterns: Theory and Evidence," Journal of Industrial Economics, Wiley Blackwell, vol. 68(4), pages 737-779, December.

 ISSN: 2582-6433

the importance of cross-border cooperation to tackle the global nature of algorithmic collusion.

India's competition law is governed by the Competition Act, 2002, enforced by the Competition Commission of India (CCI). The Act prohibits anti-competitive agreements, including cartels and price-fixing, under Section 3. However, the law primarily targets human-driven collusion and may struggle to address algorithm-driven coordination, especially when collusion is tacit rather than explicit.

The Draft Digital Competition Bill, 2024 seeks to bridge this gap by expanding the CCI's powers to regulate algorithmic practices. By adding key provisions including Ex-Ante Regulation of Digital Gatekeepers, algorithmic transparency requirement, enhanced investigatory powers. These proposals align with global regulatory trends but face implementation challenges, given the technical complexity of algorithmic systems and the need for specialized regulatory expertise.

Effective regulation of algorithmic collusion will likely require close collaboration between competition authorities and tech firms. Regulators often lack the technical expertise and resources to fully understand and monitor advanced algorithms, while companies may resist oversight out of fear of losing competitive advantages or revealing proprietary information (Calvano et al., 2020). Bridging this gap through collaborative research and knowledge-sharing could be key to developing more adaptive and effective regulatory framework

## Conclusion

The rise of Algorithmic collusion represents a profound challenge to traditional competition law frameworks, disrupting established legal doctrines and complicating regulatory enforcement. As algorithms increasingly drive market decisions, their ability to autonomously learn and sustain collusive outcomes without human intervention pushes the boundaries of existing antitrust laws, which were designed to regulate human behaviour rather than machine-driven optimization processes.

The complexity of algorithmic collusion lies in its ability to blur the lines between intentional and unintentional anti-competitive practices. While explicit collusion facilitated by deliberately programmed algorithms can still be addressed under current laws, tacit algorithmic collusion — where algorithms independently learn to avoid price wars and sustain supra-competitive

 ISSN: 2582-6433

prices — remains a gray area. The requirement to prove intent or a formal agreement, which has traditionally been the cornerstone of competition enforcement, becomes increasingly impractical in the face of self-learning AI systems.

Jurisdictions around the world are beginning to adapt to this evolving landscape. The European Union, through legislative instruments like the Digital Markets Act, has taken proactive steps to curb algorithmic anti-competitiveness, while the United States and Australia are ramping up their scrutiny of digital platforms. India's legislative efforts, particularly through the Draft Digital Competition Bill, 2024, signal an important step toward modernizing domestic competition law. Provisions that mandate algorithmic transparency, ex-ante oversight, and enhanced investigatory powers for the Competition Commission of India (CCI) are promising measures, but their effectiveness will hinge on robust implementation and continuous adaptation to technological advancements.

Addressing algorithmic collusion requires a multifaceted approach. Ex-ante measures, such as mandatory algorithm audits and sandbox testing, could help preempt collusion before it distorts markets, while ex-post enforcement supported by algorithmic monitoring systems could enhance regulators' ability to detect and respond to collusive patterns in real time. International cooperation will also be crucial, given the cross-border nature of digital markets and the risk of jurisdictional arbitrage.

Ultimately, the balance between promoting innovation and safeguarding market competition will be a delicate one. Firms should be incentivized to adopt competitive algorithms that enhance consumer welfare, but they must also bear responsibility for the unintended consequences of deploying self-learning systems. Policymakers, regulators, and technologists will need to work collaboratively to develop agile legal frameworks capable of evolving alongside AI-driven markets.

As technology continues to reshape global commerce, competition law must evolve from its human-centric origins to address the realities of algorithmic coordination. The challenge is formidable, but with proactive regulation, enhanced investigatory tools, and sustained international collaboration, regulators can mitigate the risks of algorithmic collusion while preserving the core principles of market fairness and consumer protection.