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Silent Coordination: Reputation, Signaling and Collusion Windows in the Global Semiconductor Logistics Industry

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Abstract: *The research aims to analyse the impact of strategic signalling, artificial intelligence-driven decision-making systems, and regulatory uncertainty on tacit coordination within oligopolistic markets. With technological development, firms can coordinate effectively through observable signalling and automated actions without direct communication. Therefore, to tackle the problem, the paper develops a Dynamic Stackelberg Collusion Model that integrates theories of Stackelberg competition, Bayesian beliefs, regime switches, reputation dynamics, enforcement signals, and the probability of tacit collusion. Within this model, it is proposed that strategic signalling from leading firms, reputation, market concentration, Bayesian reasoning, and pricing automation systems considerably affect the probability of tacit coordination. The results of this research demonstrate how strategic interactions have become increasingly sophisticated in today's highly technological and competitive oligopoly, with simultaneous influences from innovation, AI, market concentration, and regulation on industry participants. The semiconductor logistics industry seems to be an appropriate example for analysing strategic interaction in modern markets, since it involves high entry barriers, substantial investment, and a high degree of operational digitalisation. The research has shown that phenomena such as strategic signalling, reputation formation, Bayesian games, and AI pricing mechanisms may affect the tacit coordination of market players even without explicit collusion agreements. In addition, dynamic changes in market conditions, especially during disruptive times, are important in shaping strategic decisions and coordinating firms' incentives.*

Keywords: *Tacit Collusion, Stackelberg Competition, Reputation Dynamics, Signalling, Dynamic Games, Oligopoly Markets, Antitrust, Semiconductor Logistics.*

Nomenclature:
SDU: Strategic Dynamics Unit

I. INTRODUCTION

The objective of this research paper is to examine the evolving dynamics of strategic interdependence, tacit coordination, and regulatory issues in the global semiconductor logistics industry, which is characterised by uncertainty and technological change. According to [1], game theory has become a widely used tool for modelling interactions between an attacker and a defender.

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A new model for the paper, referred to as the Dynamic Stackelberg Collusion Model, incorporates Stackelberg competition, Bayesian belief updating, regime switching, reputation dynamics, enforcement signals, and tacit collusion probabilities. The current research analyses how leader-follower relationships, signalling strategies, artificial intelligence-based price setting, and market concentration affect the likelihood of tacit collusion. At the same time, the effects of regime uncertainty, the strictness of enforcement measures, and artificial intelligence-based market regulation are considered.

This study makes an important contribution to the growing body of work on industrial organisation, competition policy, digital markets, and logistics economics by tackling key issues of algorithmic coordination and the use of artificial intelligence in market functioning. Additionally, it offers an important theoretical and empirical foundation for investigating firms' strategies for maintaining market stability, investing in infrastructure, and complying with regulations in oligopolistic markets.

II. LITERATURE REVIEW

The semiconductor logistics industry is a highly concentrated market with high barriers to entry, massive investments, sophisticated technology and intense interdependence between rival companies. These features can lead to situations in which one company's strategy may affect other companies' behaviour, actions, and results. In digital industries, the problem becomes even more complicated due to the adoption of artificial intelligence, big data analysis, and algorithm-based decision-making in business processes. As [2] As pointed out, contemporary digital markets have changed the nature of competition; as a result, identifying coordinated behaviours among firms has become challenging for competitors and regulators. The increasing relevance of tacit coordination has led to a resurgence in research in industrial organisation. Firms might coordinate through observed market behaviour, pricing behaviour, and other observable activities rather than through explicit coordination. For example, [3] found that autonomous pricing algorithms could discover cooperative strategies in repeated interactions, thereby revealing the potential for coordinated actions that might arise from an algorithmic process despite the system having no intentionality. AI-based dynamic pricing has significant potential to improve firms' profitability. Companies will take advantage of price personalisation, which considers individuals' behaviours and traits, as well as reducing costs through efficiency and automation [4].

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Strategic coordination theories are based on the concepts developed within Stackelberg competition and leader-follower models. The current research shows that the concept of first-mover advantage still holds for markets where firms possess monopolistic power to set prices, output, and capacity, and to form expectations within an oligopoly. The Bayesian learning framework is another approach that sheds light on the decision-making process under conditions of uncertainty. Firms update their forecasts using information obtained from their competitors and the market. According to findings from [5], learning frameworks grounded in empirical evidence help companies improve their predictions of rivals' moves and increase strategic adaptability. The use of the Bayesian framework is especially relevant when operating under highly dynamic conditions.

AI has proven to be one of the most important innovations in logistics and supply chain management. Predictive systems, maintenance, and pricing solutions offer opportunities to boost operational effectiveness and improve market transparency. As noted by [6], digital logistics solutions have become one of the most valuable means of ensuring greater resilience and more accurate forecasting. Nevertheless, increased transparency might also create conditions under which companies can better track their competitors' performance and adapt their strategy to those changes. In today's world, the issue of regulating algorithmic coordination and digital market conduct has gained significant importance. Beyond traditional signs of coordination, competition regulators are examining patterns of market behaviour, pricing strategies, and interactions among algorithms. Collusion (implicit and explicit) may be nothing new, but algorithmic price-fixing is novel in terms of detection, enforcement, and regulatory problems [7].

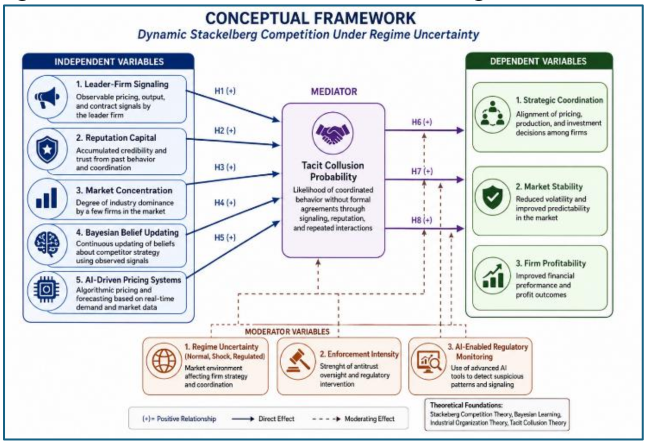
Reputation is yet another vital determinant of strategic behaviour in the long run. Companies in concentrated markets might have incentives to develop their reputation, as it is an important determinant of future cooperation and dealings with consumers. According to some researchers, reputation is a soft form of corporate governance that can encourage firms to behave predictably in the market environment. Accordingly, strong reputation-related incentives can facilitate tacit coordination by constraining opportunistic behaviour.

Finally, the issue of regime switching is also vital. The semiconductor industry has faced major regime shifts driven by geopolitics, technological limitations, and regulatory changes. The Research aims to demonstrate how companies change their approaches to strategy-making depending on the market regime. Thus, a Markov regime-switching model can be applied to analyse such shifts. Another area of recent interest has been the interplay between strategic coordination and regulatory enforcement. For example, [8] develops a welfare–Nash framework which illustrates the impact of externalities on both cooperative and competitive strategies. In the same vein, [9] demonstrates how well-suited Stackelberg Q-learning algorithms are for modelling strategic adaptations in environments where multiple uncertain agents compete.

Nevertheless, current knowledge gaps lie in the fact that very few articles have incorporated all six factors into a single framework: Stackelberg leadership, Bayesian learning, reputation building, regime switching, signalling enforcement mechanisms, intelligent pricing, and probabilities of tacit collusion. This is where the Dynamic Stackelberg Collusion Framework plays an essential role. This framework will provide a comprehensive analysis of the complex relationships that define strategic coordination in sophisticated markets. Moreover, the Dynamic Stackelberg Collusion Framework can contribute significantly to ongoing discussions on contemporary competition policy and, more broadly, supply chain economics.

III. CONCEPTUAL FRAMEWORK

The suggested conceptual framework analyses the impacts of strategic and technological determinants on coordination and performance outcomes in oligopolistic logistics for the semiconductor market. The conceptual framework is based on Stackelberg Competition Theory, Bayesian Learning Theory, Industrial Organization Theory, and Tacit Collusion Theory. It describes how organisations operating in concentrated industries can coordinate strategically through signals, without direct communication among them.



[Fig.1: Conceptual Framework Dynamic Stackelberg Competition Under Regime Uncertainty (Made by Biorender)]

The independent variables will include Leader Firm Signalling, Reputation Capital, Market Concentration, Bayesian Belief Updating, and AI-Driven Pricing Systems. Algorithms seem to be progressively replacing people when making decisions about pricing goods and services. To examine the potential implications, we will use experimental methods to study the behaviour of artificial intelligence (Q-learning) algorithms in a benchmark oligopoly pricing game [10]. Leader firm signalling includes behaviours such as changes in prices, output, and contracts that affect competing firms' expectations. Reputation capital refers to the accumulated trust that firms have regarding their predictability in the market. Market concentration refers to the situation in which a few firms dominate industries. Bayesian belief updating involves firms revising their expectations about competitors based on market information signals [11]. debated on whether or not pricing algorithms may engage in collusion to make supra-competitive profits without any communication between them. The dependent variables consist of Strategic Coordination, Market

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Stability, and Firm Profitability. Strategic coordination refers to how well firms coordinate their decisions regarding pricing, production, and investments. Market stability means less variability and greater certainty in the semiconductor logistics industry. Firm profitability encompasses profits achieved through strategic coordination and market stability.

The above-mentioned determinants are said to influence Tacit Collusion Probability, which acts as the mediating factor. Tacit collusion probability is the probability that firms act in concert without an explicit agreement, relying on signalling, reputation, and repeated actions. In addition, three moderating factors have been included within the conceptual model: Regime Uncertainty, Enforcing Intensity, and AI-Enabled Regulatory Monitoring. The Regime Uncertainty factor comprises Normal, Shock, and Regulated market scenarios that can affect corporate decision-making. The Enforcing Intensity factor considers the strictness with which antitrust regulation is enforced. In contrast, the AI-Enabled Regulatory Monitoring factor addresses the use of artificial intelligence in analysing competition-related market behaviour.

IV. RESEARCH METHODOLOGY

This paper proposes a quantitative, theory-based research methodology to investigate the factors underlying the development of tacit coordination and strategy in oligopolistic markets characterised by uncertainty. In doing so, the research incorporates a conceptual framework that combines Stackelberg competition, Bayesian belief revision, reputation effects, enforcement signals, regime-switching uncertainty, and price setting via AI. A dataset will be created via Monte Carlo simulation for a hypothetical firm operating within three different market regimes (Normal, Shock, and Regulated). The PLS-SEM statistical technique will be used to examine the hypothesised relationships among signalling by the leading firm, reputation capital, market concentration, Bayesian belief, AI price setting, probability of tacit collusion, coordination and strategies, market stability, and firm profitability. The probability of tacit collusion is considered the mediator, while regime uncertainty, enforcement, and AI-enabled regulation constitute the moderators. This paper tests reliability, validity, mediation, moderation, and path analysis using Smart PLS 4.0.

V. RESEARCH QUESTIONS

1. RQ1: What effect does the signalling by leaders to firms have on the probability of the occurrence of tacit collusion in the oligopoly market for semiconductor logistics?
2. RQ2: How does reputation capital affect tacit coordination between competing firms?
3. RQ3: How does the switching environment (Normal regime, Shock regimes, and Regulated regime) affect strategic coordination?
4. RQ4: In what way does Bayesian belief updating affect the reaction of follower firms to strategic signals by leader firms?
5. RQ5: How does the level of enforcement intensity affect tacit collusion and strategic coordination?
6. RQ6: How do Artificial Intelligence-based price and forecast systems contribute to indirect coordination?
7. RQ7: How does the concentration of the market contribute to tacit collusion?
8. RQ8: How do Shock regimes affect the relationship between strategic signalling and tacit coordination?
9. RQ9: How does tacit collusion affect market stability and profitability?
10. RQ10: How does AI-assisted monitoring for regulation affect tacit collusion?

A. Research Hypotheses:

i. Direct Effects

1. H1: The effect of signal transmission by leaders to their firms will positively affect the likelihood of tacit collusion.
2. H2: The effect of reputation capital will positively affect the likelihood of tacit collusion.
3. H3: The effect of Bayesian beliefs will positively affect follower strategy in alignment with the leader.
4. H4: The likelihood of tacit collusion will positively affect market stability.
5. H5: The likelihood of tacit collusion will positively affect firm profitability.
6. H6: The effect of enforcement intensity will negatively affect the likelihood of tacit collusion.
7. H7: The use of pricing and forecasting algorithms using AI

ii. Mediation Hypotheses

8. H8: The likelihood of tacit collusion mediates the connection between leadership-signalling and market stability.
9. H9: The likelihood of tacit collusion mediates the connection between reputation capital and firm profitability.
10. H10: The likelihood of tacit collusion mediates the connection between market concentration and strategic coordination.

iii. Hypotheses on Moderation Effects

11. H11: Regime uncertainty moderates the relationship between leader-firm signalling and the probability of tacit collusion, such that the relationship is more pronounced in Shock Regimes than in Normal Regimes.
12. H12: Enforceability strength moderates the relationship between reputation capital and the probability of tacit collusion, such that the relationship is weaker for stronger enforcement.
13. H13: Artificial intelligence-based regulatory surveillance moderates the relationship between strategic signalling and the probability of tacit collusion such that the relationship becomes weaker.

Note that the model can be used for empirical testing in the future through:

a) PLS-SEM,
b) Monte Carlo simulation,
c) Bayesian modelling, and
d) Dynamic game theory.

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B. THE CASE

i. Background of the Case: Quantumaxis Freight Systems

Quantum Axis Freight Systems, established in 2015 and located in Dubai, was the most aggressive competitor to NexSpace in the semiconductor logistics market. The company expanded rapidly through acquisitions of smaller regional semiconductor freight operators in the Middle East, Southeast Asia and Europe. Nex Space has traditionally taken a more conservative approach. In contrast, Quantum Axis has aggressively adopted collusive practices to gain a competitive advantage in market-share expansion, slashing prices and winning deals quickly. But multiple price wars in 2024-26 hit the industry hard and cut deeply into Quantum Axis's profitability.

By 2027, Quantum Axis restructured its management strategies on the following:

- Industrial sustainability, including ESG (Environment, Social, Governance)
- Production/ output/ logistics decisions (demand & supply);
- Pricing strategies for normal profit (collusion strategy).

Analysts noted that NexSpace and QuantumAxis often changed freight prices on the same days. There were no formal contracts. But competition regulators started to look into whether the firms were actually coordinating via informal signals.

The semiconductor industry witnessed a massive change from 2025 to 2027. Escalating tensions, technological nationalism, the expansion of AI applications, and disruptions to international supply chains led to a significant restructuring of global logistics chains. Specialised logistics providers became key players in this domain because logistics involving the transport and warehousing of delicate semiconductor materials required specialised equipment, complex predictive modelling, climate-controlled cargo transport, secure freight monitoring, and stable political corridors. The Middle East, especially the Gulf region, rapidly became an emerging hub linking semiconductor manufacturers in Asia with consumers in Europe and North America. During this time, two leading companies in this niche market in the Middle East were NexSpace Integrated Logistics and QuantumAxis Freight Systems. The semiconductor logistics industry exhibited the typical features of an oligopoly business market structure. The entry barriers into this market were very high, as they required substantial capital investments in operating semiconductor logistics transport services, adherence to complex international regulatory requirements, and the technological expertise needed to handle electronic cargo. Few companies could enter into such a competitive business market. Market concentration was further heightened along the Middle East semiconductor logistics route.

The market leader is the NexSpace Integrated Logistics. Born of the era of technological investment in the Gulf region, NexSpace gained notoriety for its reliability, consistent pricing, and long-lasting partnerships with multinational semiconductor companies. The company was managed by the visionary CEO, Mr Daniel Mercer, who saw the business more as an infrastructure than merely a transportation company. Mercer firmly believed that the semiconductor business should be seen as a "strategic utility industry," and too much competition and endless price wars would disrupt everything.

On the other hand, QuantumAxis's expansion strategy was much more aggressive. Formed in Dubai in 2015, the firm rapidly acquired smaller freight companies in the Middle East, Southeast Asia, and portions of Europe. To gain market share, QuantumAxis actively lowered freight rates, introduced dynamic, AI-supported bidding systems, and quickly entered new shipping lanes. The company attracted significant attention for its challenging approach to established practices and its willingness to compete actively for deals involving large semiconductor manufacturers. From 2024 to 2026, intense price competition between NexSpace and QuantumAxis significantly affected the profitability of the semiconductor logistics industry. Multiple instances of active rate-cutting led to destructive freight-rate wars, undermining the industry's margins and stability. Both firms were investing heavily in infrastructure development, predictive analytics tools, and AI-supported supply chain management systems. Yet, reducing profit margins put a strain on many players in the sector. According to analysts, the semiconductor freight business became caught in a vicious cycle of intense price wars in good times and coordinated behaviour in troubled ones.

As of February 2027, QuantumAxis had started rethinking its strategy. This firm shifted from rapid expansion to sustainability-focused operations, which include production discipline and stable freight rates. Industry observers also noted that NexSpace and QuantumAxis made changes to freight rates around the same time. While there were no indications that any communication took place between them, it was apparent that some form of coordination existed, given the strategic signals each firm sent indirectly to the other.

Regulators' concerns were part of an ongoing discussion within the international community about AI-driven collusion and market coordination. Previous antitrust actions always involved investigating evidence of agreements, in writing or via email, between companies to establish collusive practices. However, in the contemporary digital marketplace, companies rely on AI algorithms, public investor statements, signalling behaviour, and AI-driven pricing systems to coordinate their actions without necessarily communicating with one another.

The use of sophisticated AI algorithms by organisations prompted European and Middle Eastern regulators to caution about potential anti-competitive practices arising from coordinated behaviour without explicit communication. Investor behaviour, including public statements, supply chain synchronisation, joint production slowdowns, and observable pricing, was a regulatory concern. It was not until mid-2026 that the European Competition Authority published its memorandum stating that signalling behaviour could be interpreted as anti-competitive conduct in the absence of agreement between the parties. This policy caused considerable concern at NexSpace, as the firm was known for relying on stable prices to manipulate market signals. The situation posed a tough strategic question for Mr Daniel Mercer. On the one hand, Mercer was convinced that

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stability in freight rates and predictability in market behaviour was beneficial to the entire semiconductor business ecosystem. As Mercer claims, constant price wars prevented any investment in infrastructure and increased risk for semiconductor producers. Moreover, stable margins enabled logistics companies to invest in state-of-the-art logistics infrastructure. However, the company's legal and compliance departments raised concerns about a potential major antitrust investigation into NexSpace. It was explained that, in today's market, regulators tend to treat consistent market behaviour as a form of collusion in itself. Such a situation could lead to significant fines, litigation against the company, reputational damage related to ESG, and long-term regulatory scrutiny. To better understand the evolving competitive environment, NexSpace created its own Strategic Dynamics Unit (SDU), comprising economists, game theorists, artificial intelligence experts, and strategic analysts. This unit created an analytical model called the Dynamic Stackelberg Collusion Framework. It consisted of several theoretical perspectives, such as Stackelberg Competition, Bayesian belief updates, regime-switching uncertainty, enforcement signals, reputation dynamics, and tacit collusion probabilities.

This model aimed to show how oligopolistic firms could coordinate their actions in concentrated digital industries, even without direct communication with one another. In this framework, NexSpace was a leading firm, while Quantum Axis was a follower firm. The former chose production levels, signalling prices, and contracts while considering potential moves by the latter firm. Still, there was uncertainty about whether the latter firm would cooperate or compete. Both companies continually monitored signals from each other and adjusted their beliefs about competitors' strategies through Bayesian updates. The market has changed in three different environmental contexts – Normal Regime, Shock Regime, and Regulated Regime. Under normal conditions, businesses operated amid more consistent market demand. During shock regimes, geopolitical changes, supply chain disruptions, or abrupt surges in demand led firms to focus more on market stability and the dependability of their infrastructure. Regulated regimes arose during periods of heightened antitrust surveillance and enforcement.

One of the most creative components of this theory is the “collusion window.” Based on Mercer and the SDU, only when there are temporary windows of high-demand uncertainty, strong reputational considerations, low enforcement expectations, and concentrated markets can the tacit coordination become sustainable. Reputations played an important role, as firms feared retaliation from other businesses for non-compliance with market norms. Thus, reputation served as an informal enforcement mechanism in this case, without any formal agreement.

On the other hand, regulators began using AI-driven enforcement tools to detect suspicious patterns in the digital marketplace. This presented NexSpace with a dilemma, as robust signals were beneficial for coordinating market behaviour and keeping prices stable, but carried the risk of regulatory enforcement action. However, the simulation conducted by the Strategic Dynamics Unit yielded some very worrying results. Moderate enforcement led to stable cooperation through tacit signalling with relatively stable results. Strong enforcement led to poor cooperation and high volatility. However, in crisis or shock enforcement situations, firms would always seek cooperation, as they were more interested in supply chain continuity than in competitive behaviour. As of mid-2027, Mercer faced perhaps the hardest decision of his life: whether NexSpace should continue to rely on signalling to maintain market stability while preserving the long-term investments made in its infrastructure, or cut costs by lowering freight prices and ceasing to coordinate behaviours that were tantamount to anti-competitive activities—the fate of NexSpace, the semiconductor logistics market, and possibly regional supply.

ii. Emerging Regulatory Concerns

Regulators in several Middle Eastern jurisdictions were increasingly concerned about algorithmic coordination and tacit collusion within the digital semiconductor industry. Traditional antitrust enforcement relied on proving formal cartel agreements. However, market economies that were increasingly characterised by indirect coordination:

- Public-investor communications
- algorithmic pricing decisions based on demand and supply
- coordinated supply chain decisions to create shortages
- predictive signalling
- AI-integrated market forecasting

The European Competition Authority released a memorandum of policy in mid-2026 suggesting it might consider observable parallel strategic signalling, without explicit interfirm communication, to constitute anti-competitive coordination, which NexSpace perceived as a direct challenge to its signalling strategy.

iii. The Innovative Conceptual Framework

The conceptual framework integrates six interdependent Strategic Dynamics Units that combine:

- Stackelberg competition;
- Regime switching uncertainty;
- Reputational dynamics;
- Enforcement signalling;
- Tacit-collusion probabilities;

The conceptual framework shows ‘how oligopoly firms display tacit coordination without any formal agreements.’ In terms of game theory, a best response refers to a case whereby a player chooses an action that maximises their payoff depending on the actions taken by other players [1]

The conceptual model framework diagram above shows the interaction between the three types of Regime environment between the leader and follower firm, and how the actions of both firms affect the strategic behaviour, pricing decisions, contract terms, collusion rewards, market demand & market power advantages represented below:

- Normal Regime Environment- stable markets
- Shock Regime Environment- supply chain disruptions
- Regulated Regime Environment- strict regulatory environment

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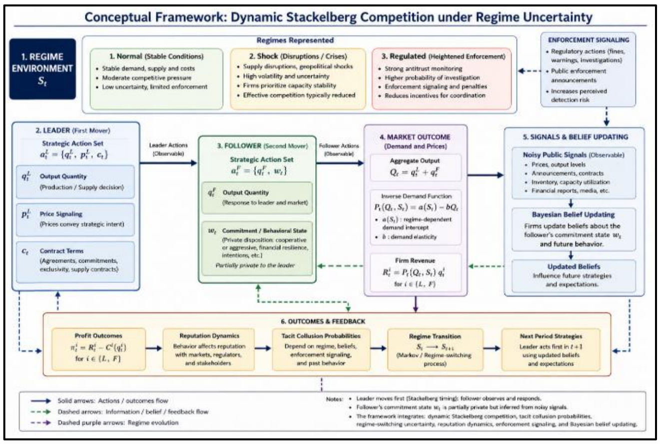
The follower's commitment strategy was Partially Private and revealed through noisy signals in the public arena [12]. studied the concept of Markov perfect equilibrium in a duopoly model, wherein the seller uses algorithms to determine his price strategy. By definition, an algorithm is a function of the competitor's price that translates into one's own price. The algorithm is determined once, but it adjusts quickly to changes in conditions. Leader employed pricing to influence followers, manage market expectations, monitor competitors' responses, or coordinate the behaviour of firms without direct communication. The leader could strategically alter output to increase market dominance, discourage new entrants, maintain price stability, or indicate fierce rivalry.



[Fig.2: Conceptual Framework: Dynamic Stackelberg Competition Under Regime Uncertainty]

iv. Players and Timing

The Game focuses on two players:

- The Leader Firm (L): NexSpace Integrated Logistics;
- The Follower Firm (F): QuantumAxis Freight Systems.

The game shows discrete periods:

[t = 1, 2, 3, 4…, T]

The market regime was developed using a finite-state Markov process: [Strategy-t {Normal, Shock, Regulated]

The model incorporates Bayesian learning, regime-switching demand, and a dynamic Stackelberg game, in which the leader first selects production, price signalling, and contract terms, anticipating the follower's best-response function. In contrast, the follower's commitment status is only partially known, generating noisy signals and inducing Bayesian belief updating that feeds back into the leader's optimisation problem, creating a dynamically changing, regime-contingent, information-sensitive Stackelberg equilibrium.

The follower's strategic action set included: [a_t^F = {q_t^F, w_t}]

- (q_t^F) follower's production/output;
- (w_t {0,1}) collusion indicator.

The probability of collusion was defined as: [P (w_t = 1) = p_t]

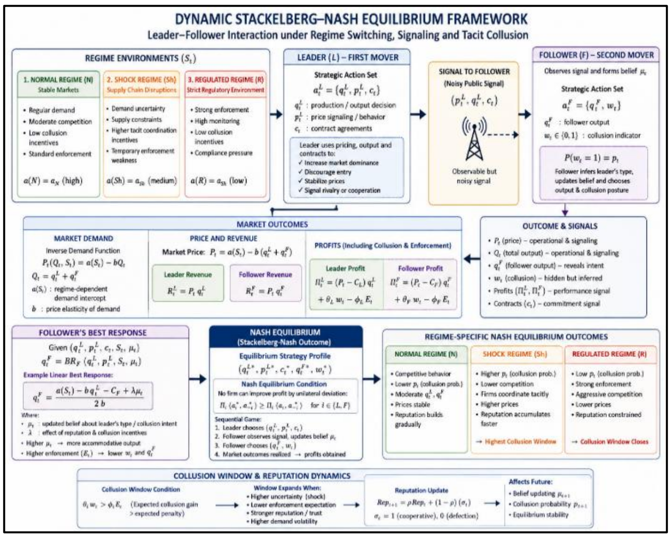
Result and Signals (Each Variable Played Operational Role as Well as Signalling Role).

The leader's strategic action set included: [a_t^L = {q_t^L, p_t^L, c_t}]

wherein:

- (q_t^L) production/output décisions;
- (p_t^L) price signalling/behaviour;
- (c_t) contract agreements.

The leader Firm's revenue is given by [R_ti = P_t (Q_t, S_t) q_i]. The shock-regime environment typically reduced competition between the leader and follower because both firms prioritised supply chain stability to meet demand during crises.



[Fig.3: Dynamic Stackelberg-Nash Equilibrium Framework]

The Nash equilibrium is determined by how the action of one firm (leader) affects the action of the other firm (follower):

- Leader (L) first mover advantage
- Follower (F) observes the leader's actions and then responds in a similar way
- Market outcomes depend on the joint actions of both the firms

Observable signalling by the leader was a key variable influencing market expectations, and the follower adjusted quantity based on market demand, expected profitability, and observable leader behaviour, indicating its strategic position or level of internal commitment, which was highly significant because it was only partially observable. The follower's choice of output revealed whether it was intended to facilitate tacit cooperative behaviour, accommodate the leader, or compete aggressively.

Aggregate output was: [$Q\_t = q\_t^L + q\_t^F$]

Market prices followed the inverse demand function: [P_t(Q_t,S_t) = a(S_t)-bQ_t]

wherein:

- (a(S_t)) regime-dependent demand intercepts;
- (b) elasticity of demand

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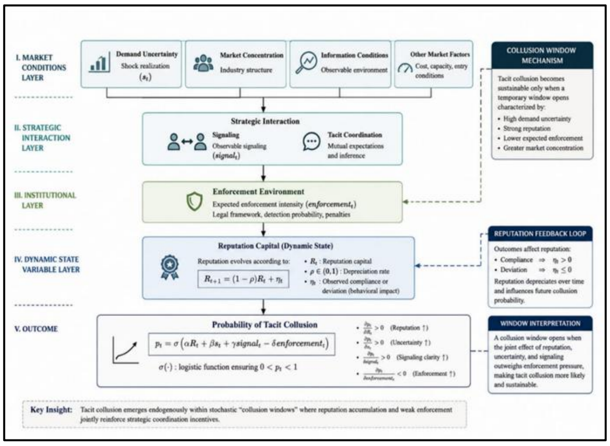

[Fig.4: Collusion Window and Reputation Dynamics Framework]

v. Collusion Window & Reputation Dynamics

A comprehensive conceptual framework depicting tacit collusion and its interaction with other independent variables is presented in Figure 3 below. According to the CEO, Mercer, tacit collaboration can only last for brief periods marked by Increased market concentration, strong reputation buildup, lower expected enforcement, and high demand uncertainty.

The likelihood of collaboration was represented as: [p_t=(_RR_t+*Ss_t*+{sig}signal_t_Enforcement_t)]

wherein:

- (R_t) represents reputation capital;
- (s_t) represents shock realisation;
- (signal_t) represents observable signalling;
- (enforcement_t) represents expected enforcement intensity.

Tacit collusion increases reputation and the likelihood of market shocks, which leads to signalling but decreases enforcement expectations, according to the collusion window and reputation dynamics framework presented above.

Expected Enforcement Intensity was captured using: [Enforcement_t = signal_t + M_t]

wherein:

- (M_t) was defined by market concentration;

It implied that signalling was an important determinant of expected regulation. Indeed, signalling was a source of strategic tension in that:

- it strengthened coordination, but
- It also led to higher levels of enforcement.

The expected intensity of enforcement was modelled by: [Enforcement_t = signal_t + M_t]

wherein: (M_t) represented market concentration;

A strategy dilemma emerged:

- The more signalling that took place, the better the coordination.
- The more signalling that took place, the more probable enforcement was.

VI. DISCUSSION

A. Description of the Payoff Structure and Dynamic Model

Payoff is a measure of the profit each firm makes after accounting for the costs and risks of the business.

B. Payoff of Leader Firm (NexSpace)

$\pi\_t^L = (P\_t - c^L (q\_t^L))\, q\_t^L$ - Enf_t - Contract Cost_t

The payoff structure shows each firm's profitability, accounting for all market risks. Put simply, the payoff of the firm is defined as: revenue generated by the sale of logistics service -- operation cost -- enforcement cost – cost of contracts

Thus, the leader maximises its payoff under market coordination and risk regulation.

C. Follower Firm's Payoff (Quantum Axis)

πt^F= (Pt-cF(qtF)) qtF - Enf t – Contract Cost_t – Collusion Penalty_t

The payoff for the follower firm can be computed similarly, but it also accounts for the Collusion Penalty Cost. This cost arises from the expected penalties for regulatory action if any anti-competitive behaviour is detected. Therefore, the follower firm should factor in both economic gains and risks involved.

D. Structure of Dynamics and State Transition

The market is not always static; its state varies based on:

- Market demand
- Supply chain disruptions
- Regulatory actions
- Firm actions
- Market uncertainties

The vector X_t describes the market's present state, including elements such as market reputation, market regime, and enforcement.

The Markov Transition Matrix is employed to forecast future movements in the market's state. Examples include: A Normal State could transition to the Shock State due to geopolitical conflicts or supply chain disruptions. The Shock State could become a Regulated State owing to increased regulatory oversight.

E. Monte Carlo Simulation

The Strategic Dynamics Unit used Monte Carlo Simulation to analyse several future scenarios. It involves altering the values of certain variables repeatedly, such as:

- The intensity of enforcement
- Demand in the market
- The reputation of an individual firm
- The behaviour in signalling.

In layman's terms, Monte Carlo Simulation simulates a lab experiment for firms by predicting what may happen to their profits, coordination, and competition in different future states before they make any decision.

The model explains how the firms in Oligopoly always seek to strike a balance between these three aims:

- Maximisation of profit
- Sustainability through cooperation
- Escape from regulatory measures and antitrust actions

With increasing enforcement, the value of implicit coordination becomes lower for firms. But during market shocks and supply chain problems, cooperation remains desirable, as sustainability outweighs competition.

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- **Strategic Debate about the Case**: Should semiconductors be provided with a reliable supply chain? Should the predictability of margins attract investments? Should coordination lessen volatility? Should stability provide support for infrastructure planning?
- **Comment from NexSpace Executive**: "Price wars lead to the destruction of infrastructure industries. Stability helps everyone in the industry." The group felt that coordination was economically rational and not unethical.

The legal department strongly opposed continued signalling.

It was the fear of the compliance department that the company might be subject to:

- Substantial monetary penalties;
- litigation from investors;
- Reduced ESG rating; and
- Damaged reputation.

F. Connecting the Hypotheses to the Case

The following hypotheses are based on strategic signalling actions taken by NexSpace Integrated Logistics and QuantumAxis Freight Systems from 2025 to 2027. The case demonstrates how strategic signalling, reputation management, artificial intelligence, market concentration, and government regulation influence tacit coordination within a concentrated semiconductor logistics market.

H1: Leader Firm Signalling and the Probability of Tacit Coordination

NexSpace served as the leading firm in the market and employed several signalling actions, including price and production signalling. Industry analysts also noted that the two companies made simultaneous changes to their freight rates despite there being no agreement between them. This indicates that signalling contributed to the probability of tacit coordination.

H2: Impact of Reputation Capital on Probability of Tacit Coordination

NexSpace had a good reputation for reliability, stable pricing, and loyal customers. According to the case, a reputation factor helped ensure that both parties followed through on what was expected in the market, as both companies were concerned about possible retaliation and reputational damage. Therefore, the higher the reputation capital, the more sustainable the tacit coordination.

H3: Bayesian Belief Updating and Strategy Follow-Up of the Follower

According to the Strategic Dynamics Unit, QuantumAxis was monitoring all of NexSpace's activities and responding to them. QuantumAxis used Bayesian belief updating to update its beliefs about the leader's future strategies based on observed signals.

H4: Tacit Coordination Probability and Market Stability

In the aftermath of the highly damaging price war years (2024-2026), both firms preferred stable pricing policies. In this regard, the present case study shows that a period of enhanced tacit coordination was accompanied by increased market stability.

H5: Tacit Coordination Probability and Firm Profitability

Due to the negative impacts on the industry's profitability and infrastructure investments, the Strategic Dynamics Unit concluded that stable coordination could help preserve profits and improve financial performance. Thus, a higher probability of tacit collusion can increase firm profitability.

H6: Enforcement Intensity and Tacit Coordination Probability

The 2026 Memorandum issued by the European Competition Authority raised significant concerns regarding tacit coordination and signalling processes. Based on the results provided, one can see that higher enforcement intensity increased coordination costs and decreased the likelihood of tacit collusion.

H7: AI-driven Pricing and Forecasting Systems and Tacit Collusion Probability

Both firms made substantial investments in their forecasting, logistics, and pricing systems supported by Artificial Intelligence solutions. This helped to better understand what competitors were doing and facilitated coordination efforts.

G. Mediating Role of Tacit Collusion Probability

H8: Tacit Collusion Probability as a Mediator between Leader Signalling and Market Stability

In this case, just signalling does not necessarily lead to stable markets. Only when the signals were received and acted upon by other competitors did stability come. Thus, the probability of tacit collusion serves as the mediator here.

H9: Tacit Collusion Probability as a Mediator between Reputation Capital and Firm Profitability

As seen in the NexSpace case study, high reputation capital was one of the factors that led to predictable market behaviour. Nevertheless, profitability resulted from tacit coordination, which means that the probability of tacit collusion serves as a mediator here.

H10: Tacit Collusion Probability as a Mediator between Market Concentration and Strategic Coordination

It can be said that the semiconductor logistics market was highly concentrated and had few competitors. Market concentration gave rise to strategic coordination due to the probability of tacit collusion.

H. Moderating Effects

H11: Effect of Regime Uncertainty

In terms of market regimes, there are Normal, Shock, and Regulated Regimes. In shock regimes characterised by supply chain disruptions and geopolitical uncertainty, both firms opted for stability over competition. Thus, in Shock Regimes, the effect of signalling on tacit coordination is magnified.

H12: Effect of Enforcement Intensity

While reputation promoted coordination, enforcement intensity worked against its effect. Due to the actions taken by the European Competition Authority, the firms feared legal complications and hence became less willing to coordinate. This reduces the impact of reputation on tacit collusion.

H13: AI-Based Regulatory Surveillance as a Moderator

The case reveals the growing use of Artificial Intelligence in regulatory monitoring, as regulators aim to detect suspicious price adjustments and signalling behaviours. With increased AI-based monitoring, firms have become wary, thereby reducing the impact of strategic signalling on the probability of tacit collusion.

I. Summary

Overall, the NexSpace–QuantumAxis case has provided empirical support for all the postulated hypotheses.

VII. NUMERICAL EXPERIMENTS

Strategic Dynamic Unit (SDU) made the following assumptions:

- Past data analysis for freight rate
- Monetary penalties levied by regulatory organizations
- Signalling intensity

A. SCENARIO 1:

Assumptions:

- using moderate enforcement;
- using moderate reputation effects;
- Assuming stable market demand.

Results: The emergence of intermittent tacit cooperation was accompanied by moderate signalling intensity and tolerable welfare deficits. According to the simulations, there may be some informal collaboration without much enforcement.

B. SCENARIO 2: HIGH ENFORCEMENT ENVIRONMENT

Assumptions:

- Strong regulatory monitoring and controlling;
- High antitrust penalties;
- Increased algorithmic surveillance.

Results: There was a decrease in the frequency of collusion, a decrease in signalling behaviour, and an increase in competitive volatility. Executives concluded that tacit coordination was unstable due to strict enforcement measures.

C. SCENARIO 3: STRONG REPUTATION EFFECTS

Assumptions:

- Larger reputation parameter ();
- Slower reputation depreciation.

Results: Collusion windows expanded, deviations were punished quickly, and implicit cooperation became extremely persistent. The simulations showed how reputation can replace official agreements.

D. SCENARIO 4: FREQUENT SHOCK REGIMES

Assumptions:

- Higher Markov volatility;
- Repeated geopolitical disruptions.

Results: Temporary collusion windows became more frequent, and firms coordinated output more often, while regulators faced greater monitoring challenges.

These results are regarded as evidence that periods of crisis often promote endogenous market coordination, as businesses modify their operations to better align with implicit or tacit forms of cooperation.

A. The Case Provides Logical Reasoning for the Following Research Gaps

- whether tacit coordination improves market stability;
- how reputation sustains collusion;
- whether algorithmic signalling should trigger antitrust intervention;
- how firms balance profitability against regulatory exposure.

The case also demonstrated the growing importance of dynamic game theory in understanding modern digital oligopolies.

VIII. CONCLUSION

The study investigates the effects of regime uncertainty, enforcement, and AI-driven regulation on competition in regular, shock, and regulated market regimes. The research attempts to provide an extensive theoretical explanation of strategic behaviour in digitally interlinked sectors by integrating principles from industrial organisation, game theory, artificial intelligence, and competition economics. Also, the probability of tacit collusion impacts coordination, reputation, stability, and profitability. One can observe that the NexSpace Integrated Logistics and QuantumAxis Freight Systems case illustrate the complexity of strategic decision-making in contemporary oligopolistic industries characterised by strong interdependencies among technologies, regulatory frameworks, uncertainties, and competitive practices. It should be noted that between 2025 and 2027, the semiconductor logistics industry was highly concentrated, with only a few enterprises having sufficient resources to compete effectively.

As the market environment was complex, conventional strategies for maintaining competitiveness through high prices and independent decision-making were unsustainable in the long run. In general, one can note that enterprises operating in critical infrastructure industries can switch from overt competition to tacit coordination without any agreements. Using the Dynamic Stackelberg Collusion Framework, one can observe how strategic signals, reputation-building practices, Bayesian learning, and regime switching influence firms' decisions in digital oligopoly markets. For example, the interaction between the leader, NexSpace and the follower, QuantumAxis, firms demonstrated that both organisations consider pricing, production choices, and market responses when making decisions. Thus, it is possible to establish predictable behaviour patterns even in the absence of communication.

An important lesson learned from this case study is that tacit coordination cannot be explained by anti-competitive motives alone. Both Mr Daniel Mercer and certain NexSpace employees were convinced that market stability was economically sound and essential to the sustainable growth of the industries involved. In their opinion, the constant war between companies regarding freight rates endangered infrastructure development, diminished competitiveness and undermined profitability, ultimately destroying the entire semiconductor industry. Thus,

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the case presented poses a serious dilemma for businesses in critical industries. Should they focus exclusively on competition, despite potentially damaging effects on the industry?

On the other hand, the case also shows that, in today's world, regulatory authorities tend to view synchronised behaviour as a potential means of undermining competition. Traditionally, antitrust authorities paid special attention to agreements and communications between competitors to establish collusion. However, with the advent of AI-powered pricing solutions, algorithms, forecasters, and signalling methods, the way businesses operate has changed dramatically. Now it is clear to everyone that competitors can synchronize without any communication simply by using signals and other indirect means. The advent of algorithmic coordination poses serious challenges for competition authorities globally. From the case, it becomes apparent that competition authorities are becoming increasingly challenged in their ability to differentiate between rational responses to changes in the business environment and tacit collusion. In a volatile and uncertain environment, such as during a geopolitical conflict or a supply chain crisis, there may be instances where companies coordinate out of necessity rather than as part of a conspiracy to engage in market manipulation and maximise profits.

The simulations conducted in this case reveal that reputation and regulatory intensity play significant roles in the outcome of oligopoly. Positive reputational effects widened windows for collusion and promoted cooperation, while greater regulatory scrutiny limited signalling activities and made competition more unstable. These findings make clear that oligopoly is a dynamic system that considers not only price and quantity but also expectations and enforcement issues. The example also highlights the growing significance of dynamic game theory in modelling competition in modern industry. In oligopoly theory, static models have proven inadequate for modelling the processes that characterise an ever-evolving market environment where companies are constantly learning, adapting, and modifying their actions. The combination of Stackelberg competition with Bayesian updating and regime switching allows us to demonstrate how strategic decision-making can occur under incomplete information and dynamic changes in the market environment.

Overall, however, the dilemma faced by the CEO, Mr Mercer, persisted: to engage in signalling behaviour to ensure market stability, or to avoid coordinated behaviour and minimise the likelihood of being subject to antitrust investigations altogether? Both scenarios were associated with significant risks. With signalling, profits were stabilised, and infrastructure investments could be ensured, yet there was a threat of antitrust litigation. Without it, however, the semiconductor logistics market could fall victim to a new price war.

The case thus presents students, managers, and policymakers with a much more strategic problem regarding the future direction of competition law in digitally connected industries. As artificial intelligence, predictive analytics, and coordination without communication become more prevalent, both governments and corporations need to think carefully about the regulation, enforcement, and interpretation of competition laws in the modern age. The NexSpace case illustrates that future antitrust law might rely not just on overt collusion but also on how strategic interaction operates in a digital oligopoly.

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