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Hormuz on the Brink: Nuclear Escalation, Strategic Signaling, and Global Oil Transport Vulnerabilities

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Article

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Abstract

The Strait of Hormuz is a strategic maritime bottleneck in the global transportation of energy; however, the existing literature remains discontinuous on the nature of how geopolitical action transforms into system risks in oil supply chains. This study concentrates on the play-off of strategic signaling, risks of nuclear escalation, and chokepoint vulnerability through the application of a qualitative research design through a systematic review of literature and critical conceptual synthesis. The findings suggest that strategic signaling and nuclear-related rhetoric are major factors that lead to the formation of risk perceptions of shipping companies, insurers, and international energy markets. These perception mechanisms may tend to be both operationally and financially effective, including rerouting vessels, increased insurance premiums and oil price volatility, although there is no actual conflict or physical disruption. All this is compounded by the structural constraints of the Strait of Hormuz, which transform local geopolitical indications into a systemic upheaval of world energy flows.

There is a significant gap in the literature, such as the absence of a synthesized framework of geopolitical signaling and the structural vulnerability of maritime systems. It integrates Strategic Signaling Theory and Chokepoint Vulnerability Theory to argue that maritime risk is a co-production of the policy of states, the cognition of markets about it, and reliance on infrastructures. This study concludes that global oil transport risk is a complex, intertwined system in which perception and structure contribute to systemic vulnerability, and a combination of integrated governance and risk management strategies is required.

1. INTRODUCTION

The Strait of Hormuz, which borders both Iran and Oman, is widely regarded as one of the most important marine bottlenecks in global energy infrastructure because of its central role in the international transport of crude oil (Shepard & Pratson, 2020). Nonetheless, its significance cannot be interpreted as a simple geographical or logistical one; it is more a manifestation of a structural dependency in which global energy security is placed in the hands of a single narrow route. This concentration has systemic exposure, in which local uncertainty is sent disproportionately through the global energy and financial systems (Healy et al., 2019). Even small disruptions or unclear signals in such circumstances can create an impact that is not related to the actual physical unrest, and it shows how global expectations are sensitive to perceived instability (Ahmed et al., 2025).

Over the years, the Strait has developed from a comparatively stable transit route into a politically charged and tactical battleground. The increasing geopolitical strain in the Gulf area has helped create a cycle of episodic conflict that involves naval deployment, sea interception, and rhetoric (Roberts, 2025). Although these moves can be explained using Strategic Signaling Theory as rationality in communicating intentions and deterrence, this explanation presupposes a certain degree of interpretive consistency, which is hardly ever found in practice (Connelly et al., 2025). In practice, signals are not received in an inert manner but are actively reconstituted in fragmented institutional settings. This creates instability in

the analysis, where a signal can create deterrence, uncertainty, or escalation at the same time when seen by different actors.

At the structural level, Chokepoint Vulnerability Theory emphasizes the inherent vulnerability of the flow of strategic commodities, such as oil, owing to the geographic concentration of global supply chains (Guo et al., 2026). However, the position of vulnerability as a structural phenomenon downplays the importance of anticipatory behavior in creating system consequences. Although the Strait interruptions are often highlighted, observations indicate that instability is as likely to manifest without a physical disruption and is often fueled by risk anticipation in the global energy markets. This means that vulnerability is not merely a material state but is dynamic and created by perception and interpretation (Dokas et al., 2023).

Such dynamics are especially noticeable in the conduct of major market players. Shipping firms, insurers, and energy traders do not react only to confirmed events but constantly change their strategies depending on perceived geopolitical cues and risk situations (Atanassova et al., 2025). These kinds of reactions suggest that the risk is not in the physical chokepoint itself but rather in decision-making processes that interpret and take action in the face of uncertainty. Nevertheless, the current literature analytically disaggregates structural vulnerability, signaling processes, and market behavior and obscures the processes by which systemic risk is created (Sinani et al., 2026).

To overcome this shortcoming, this study formulates a combined qualitative model that connects strategic signaling to chokepoint vulnerability. It posits that risk in the Strait of Hormuz can be perceived as an emergent process of interplay among geopolitical communication, institutional sense-making, and structural dependency (Chaziza & Lutmar, 2025). Instead of viewing risk as an external shock, it is theorized to be constantly generated in a recursive relationship between these dimensions. Based on this, the focal question that will help guide this study is as follows: What is the interaction between strategic signaling and chokepoint vulnerability in influencing the perceived and material risks in international oil transportation over the Strait of Hormuz?

This research transcends reductionist explanations that focus on either material structure or political action by theorizing the Strait as a signaling environment and a structurally constrained energy corridor (Calzada & Eizaguirre, 2026). It shows that systemic instability develops through interpretive and anticipatory processes as well as physical geography, and points out the constitutive aspects of perception in the translation of market and logistical reactions to geopolitical indications (Yi et al., 2025). By doing this, this study adds to a more critical and system-based thinking of maritime security and energy geopolitics, especially in the context of the construction and operationalization of risk in world energy networks.

This study develops an integrated analytical framework that links nuclear escalation risk, strategic signaling, and chokepoint vulnerability in the Strait of Hormuz. It posits that the interaction between nuclear-related threat perceptions, geopolitical signaling, and structural dependence on a critical energy corridor jointly produces such maritime risk. Contrary to existing studies that examine these dimensions

in isolation, the analysis demonstrates that nuclear rhetoric and strategic ambiguity intensify perception-driven responses, which translate geopolitical signals into systemic volatility within global oil transportation systems.

2. LITERATURE REVIEW

2.1 Geopolitical Context and Strategic Signaling

The Strait of Hormuz is generally considered to be one of the most important maritime chokepoints in the global energy system, allowing the passage of a large portion of internationally traded crude oil (Wang et al., 2024). It is not only geographically important but also has strategic value because of its extreme concentration of flows and lack of other economically viable alternative shipping channels (Meza et al., 2022). This systemic design makes the Strait a systemic node in global energy security, in which any form of disruptive behavior could cause disproportionate macroeconomic and geopolitical impacts (Jugović et al., 2025).

Geopolitically, the Persian Gulf has been a never-ending source of strategic competition, especially involving Iran and foreign maritime powers (Zardoshti Zadeh Yazdi et al., 2026). The fact that the northern coast of the strait is geographically under Iranian control gives it asymmetric strategic power to the world in its energy flows, as it can exert coercive power without necessarily escalating to direct military confrontation (Prussi et al., 2021). This is indicative of a larger structural situation in maritime geopolitics, whereby the concept of geography itself is a kind of latent strategic power (Bednarski et al., 2025).

In this context, strategic signaling is a key process in interstate interactions. States use visible but imprecise signals to convey deterrence and settle, such as naval buildups, missile launches, intercepting ships, and rhetorical escalation to communicate (Ünlü, 2024). Nevertheless, the current literature tends to presuppose the comparative stability of signal reception among audiences, which is becoming more questionable in highly securitized and information-dense maritime settings (Akbarzadeh & Saba, 2025).

In reality, there is no homogeneous interpretation of signaling in the Strait of Hormuz, but rather a heterogeneous institutional processing of the signaling. The security and deterrence system is used by state actors to understand the signals sent, and the risk, volatility, and uncertainty management system is used by non-state actors, such as shipping companies, insurance companies, and energy traders (Astaíza-Gómez, 2025). Such a deviation creates a multilayered interpretive effect, where one geopolitical act can create a number of meanings, often conflicting ones.

Consequently, strategic signaling serves not only as diplomatic communication but also as a cross-domain informational shock that will not only transforms geopolitical expectations and economic risk ratings and provides a new interpretation of the concept (He & Niu, 2018). The identical message that conveys deterrence at the interstate level can cause instant changes in freight rates, insurance rates, and energy market instability (Chen et al., 2024).

Therefore, strategic signaling should not be understood as a linear transmission of state intent but rather as a systemic process of uncertainty production, in which geopolitical actions are continuously interpreted, reinterpreted, and transformed into economic risks within interconnected global systems (Antonilli, 2022). These dynamics are illustrated in the conceptual framework developed in this study, which demonstrates how signals interact with chokepoint vulnerability through perception-mediated mechanisms to generate both perceived and material risks in global oil transportation.

2.2 Chokepoint Vulnerability and Systemic Risk Dynamics.

Chokepoint Vulnerability Theory conceptualizes maritime chokepoints as limited nodes in global supply chains that disruptively cause disproportionately significant system effects (Verschuur et al., 2025). It is based on the spatial concentration of flows that are narrow geographic corridors that create structural dependency in international trade systems. The Strait of Hormuz is an illustration of this situation, as it is densely populated in terms of oil transportation, and alternative routes are not feasible (Pratson, 2023).

However, the prevailing applications of this theory are mostly structural and event-based, which consider vulnerability to be a fixed state that is triggered by physical interferences such as blockades or attacks (Meza et al., 2022). This supposition assumes a one-to-one causal relationship between material interference and an impact on the system, which is progressively inadequate to explain contemporary maritime hazardous settings. Empirical data indicate the determinative role of anticipatory behavior in the determinants of systemic outcomes. Shipping companies change directions owing to perceived geopolitical risks, insurers change premiums owing to uncertainty, and energy markets put expectations of disruption into pricing mechanisms (Tsantis et al., 2026). These reactions suggest that vulnerability is both geographical and perception-based and institutionally mediated.

Moreover, the risk has further lost its connection to the physical events that can be observed because of the growing prominence of asymmetric maritime threats, such as cyberattacks, unmanned systems, and covert sabotage (Clavijo Mesa et al., 2024). These threats enhance uncertainty without necessarily causing material disruption, thus cementing the contribution of perception to vulnerability. In this vein, vulnerability to chokepoints is to be redefined as an interdependent process between structural constraints and prospective behavioral reactions in the context of uncertainty, as opposed to a given geographic exposure (Moravej et al., 2026).

2.3 Theoretical fragmentation: Signaling vs. Structural Approaches.

One key weakness in the existing body of literature on maritime insecurity is that the Strategic Signaling Theory and Chokepoint Vulnerability Theory continue to be theoretically fragmented. These paradigms have evolved along different analytical paths, giving rise to a fragmented interpretation of the formation of risk in vital maritime systems (Ćelić et al., 2025). Strategic Signaling Theory is also based on intentionality epistemology, the importance of states in creating signals that explain deterrence, capabilities, and resolve (Connelly et al., 2025). However, this presupposes a fairly constant

interpretation, which ignores the interpretive instability that occurs when signals are interpreted by non-state actors who are heterogeneous when complex global systems are considered (Murphy & McGandy, 2026).

Conversely, the Chokepoint Vulnerability Theory is geographically and infrastructurally deterministic, and makes geographic concentration and infrastructural rigidity the two main factors of systemic risk (von Malmborg, 2024). Although this is an explanation of exposure, it assumes that vulnerability is exogenous and even static, whereby political communication and perception play a central role in the amplification of risk (Astaíza-Gómez, 2025). This division poses an explanatory disjunction: signaling theory does not clarify structural amplification in communication, whereas vulnerability theory does not clarify communication in structure. Consequently, both frameworks fail to explain the effects of geopolitical activities on systemic economic disruption (Erzurumlu et al., 2025).

This weakness is especially prominent in the Strait of Hormuz, where geopolitical cues are constantly redefined using market-based risk logics. Shipping companies, insurers, and energy traders do not act out of the will of the state but rather in response to perceived risk based on ambiguous signals in interaction with structural constraints (Chi et al., 2025). In this respect, the body of literature does not contain a cohesive framework that can explain the combination of strategic communication, interpretation systems, and structural dependency to generate systemic maritime risk.

2.4 Integrated Mechanism: Recursive Risk Production Model

This study defines risk in the Strait of Hormuz as a self-produced and endogenous, recursively maintained system that is produced when the interaction of strategic signaling and the vulnerability of the chokepoint is involved (Mišković & Wang, 2025). Geopolitical communication does not work autonomously but derives meaning through the interpretive mechanism that exists within global shipping, insurance, and energy markets, where uncertainty is the key motivator of action (Saidi et al., 2026). This mechanism represents a conceptual conflict between purposeful communication and structural amplification. Strategic signaling generates ambiguity in the system, which cannot be resolved by direct interpretation but rather transformed into probabilistic risk assessments by non-state actors that act in the system under uncertainty (López et al., 2025). They react via individually rational anticipatory measures (rerouting, hedging, and repricing), which are destabilizing as a collective.

Since the Strait of Hormuz is a narrow chokepoint that is not redundant, such distributed responses are structurally amplified to disrupt energy flows and pricing structures around the world (Kertzer et al., 2020). Notably, the disruptions do not become dead ends; they are re-internalized into the geopolitical sense and add to the strategic significance of the Strait and serve as an incentive for further signaling (Emblemsvåg & Emblemsvåg, 2025). This creates a recursive feedback loop in which signaling leads to uncertainty, and uncertainty leads to anticipatory market behavior and vice versa. Therefore, risk cannot be an external shock but a systemic production of interaction between communication and structure, which is constantly reproduced.

This literature indicates that the dangers posed by the Strait of Hormuz are co-produced as the reaction of a strategic signal jointly with structural vulnerability, wherein the responses to perceptions turn the uncertainty of geopolitical nature into concrete challenges in the transportation of oil globally.

2.5 Nuclear Signaling as a Systemic Risk Multiplier

Nuclear signaling in the Persian Gulf, as a kind of strategic signaling, builds up systemic uncertainty on top of traditional military signaling (Gong et al., 2026). It is not so much important in the likelihood of escalation, but rather on the disastrous effects of low-probability events, which transform the perception of risk in world systems (Sin, 2026). There is a prominent state of analysis between material improbability and perceptual amplification in the literature. Although nuclear escalation is not a likely outcome, nuclear rhetoric and protests have a disproportionate impact on expectations within insurance markets and shipping logistics, as well as energy pricing systems (McMillan et al., 2026). These actors work with worst-case logic, in which impact probability is less important than the statistical probability.

This effect is structurally amplified in chokepoint regions, such as the Strait of Hormuz. Redundancy is limited, and the flow of information is high; the system-wide effect of the perceived risk is given by a small change (Yang et al., 2026). Nuclear signaling thus operates as a risk multiplier, speeding up anticipatory actions, including rerouting, escalation of premiums, and hedging the market. Notably, such responses are independent of real escalation, indicating that the instability of the system is created by perception and not material occurrences (Johnson, 2021). This means that nuclear signaling narrows down and speeds up the preexisting dynamics of the signaling vulnerability system.

2.6 Gap in the Literature and Theoretical Contribution

Although maritime chokepoints, energy security, and geopolitical signaling have been widely studied, the literature remains fragmented in both conceptual and causal terms (Runganga et al., 2025). Current literature considers signaling, structural vulnerability, and market behavior as distinct analytical units, which restricts knowledge on how geopolitical communication is converted into systemic instability (Nassary et al., 2025). Strategic Signaling Theory is still largely state-centric and intention-based, and it does not consider how signals are construed and implemented by non-state actors who are integrated into global markets (Pang et al., 2026). This undermines the importance of institutional interpretation in transforming uncertainty into material economic results.

Similarly, the Chokepoint Vulnerability Theory is structurally unchanged, where geographic concentration is the key determinant of risk, and the impact of perception, anticipation, and behavioral adaptation is ignored (Okutan & Otay, 2025). This limits its ability to explain the intensification of vulnerability, even without any physical disruption (Zhai & Lee, 2024). This study overcomes these limitations by formulating a single recursive risk model in which strategic signaling and chokepoint vulnerability are two co-constitutive processes. Systemic risk is not theorized as an external shock but as the product of ongoing communication, perception, and structural constraint interaction.

Therefore, this study seeks to bridge the gap between security studies and maritime economics by redefining risk as a relational and recursive process, thereby providing a more holistic account of volatility in global oil transportation systems.

3. METHODS AND MATERIALS

This study adopts a qualitative research design based on a literature review and conceptual analysis to explore the interplay between strategic signaling and chokepoint vulnerability to create both perceived and actual risks in international oil transportation in the Strait of Hormuz. The study is based on an interpretivist epistemological position that acknowledges that maritime risk is co-created as a result of geopolitical action, institutional meaning-making, and structural limitations, instead of being an object and a wholly material phenomenon.

Peer-reviewed literature, academic monographs, and policy studies located through a structured search of major academic databases (Scopus and Web of Science) were used to conduct the systematic review. The keywords were strategic signaling, Strait of Hormuz security, chokepoint vulnerability, and maritime risk. To ensure that the studies remained relevant to the current geopolitical and energy market dynamics, the review gave preference to those published between the period of 2018 and 2026. The inclusion criteria were academic rigor, methodological transparency, and relevance to maritime geopolitics and energy security, and the exclusion criteria removed non-scholarly and superfluous literature.

Data analysis was conducted in two phases using a qualitative approach that involved thematic synthesis of the data and analysis of the data using a mechanism-based approach. The first step was to code the literature into analytical themes: strategic signaling, perceived risk formation, market and insurance responses, and structural chokepoint constraints. Second, a comparative synthesis was performed to determine the causal relationships and patterns of interaction between these themes. This enabled the reconstruction of a recursive explanatory mechanism between geopolitical signaling and anticipatory market behavior and structural amplification in the Strait of Hormuz.

The complexity of the research problem and the interaction of political communication, economic interpretation, and infrastructural dependency justify such a methodological design. The qualitative approach allows for the harmonization of disjointed disciplinary knowledge and provides a more in-depth insight into the way in which uncertainty is created and applied in the context of interdependent world systems. In this regard, this approach is suitable for explicating how perceived and material risks are co-produced in maritime energy corridors.

4. FINDINGS

The results show that the Strait of Hormuz is a structurally overdetermined geopolitical-economic chokepoint in which strategic signaling and infrastructural concentration co-produce statistically observed systemic volatility in the world oil transportation and pricing systems. The existing empirical

data on several episodes of escalations, such as the tanker incidents of 2019 with vessel seizures and deliberate maritime assault, reveal that even small-scale disruptions of sub-blockade levels are related to instant and quantifiable oil price volatility reactions in the Brent crude markets, although they are not accompanied by a prolonged physical supply shock. This trend is in line with the energy market literature, which has shown that through the processes of volatility transmission driven by expectations, geopolitical risk is quickly internalized into oil prices (Min, 2022). These findings suggest that the Strait is a high-sensitivity transmission node, as a result of which informational shocks are transformed into macroeconomic price adaptations in the short time horizons.

The main transmission channels through which strategic signaling in the Strait occurs are perception-based channels through which the global financial and logistics systems operate, and not direct interstate communication. The processes of naval deployments, missile tests, and vessel interception do not yield homogeneous interpretations but are handled in heterogeneous institutional structures, especially shipping insurance markets, freight indices, and commodity derivative systems. The Protection and Indemnity (P&I) premiums reflect evidence of nonlinear risk repricing under uncertainty conditions, with all data on maritime insurance markets showing a sharp rise in ((P&I) premiums, usually between 20% and 300%, when geopolitical tension is high (Li et al., 2026). This is backed by the financial risk literature, which has shown that uncertainty premiums are systematically above the expectations of realized losses because of anticipatory pricing in globally integrated markets (Liu et al., 2020). Therefore, signaling can be viewed as a volatility transmission system, as opposed to a regulated diplomatic communication system.

The vulnerability to chokepoints is empirically demonstrated to be produced endogenously due to anticipatory behavioral adaptation and not simply given by geographic constraints. Although classical maritime economics views structural concentration as the key factor influencing vulnerability (Gnangnon, 2022), AIS-based behavioral data suggest systematic rerouting, convoying, and vessel speed change in times of geopolitical tension, even when physical blockage does not occur. These trends show that the activation of vulnerability is facilitated by the formation of expectations and risk-adjusted optimization, as opposed to an exogenous disruption. Rerouting to other routes, such as the Gulf of Oman, is also evidence that companies are restructuring logistic networks according to risk perception, not actual need.

The nonlinear aggregation effects of AIS-derived behavioral responses are also consistent with the complex network propagation theory. Marginal rerouting and transit delays are micro-level adjustments in operations that add up to macro-level inefficiencies in oil logistics worldwide, adding to effective transit times and insurance exposure in interdependent supply chains. The literature on network science affirms that transport systems that are tightly coupled are disproportionately sensitive to local perturbations; thus, when there is a perturbation in central nodes, the system is vulnerable to cascading effects (Petropoulos et al., 2026). This confirms that the Strait is a systemic amplifier that is part of the global energy network topology.

This provides a recursive mechanism of risk amplification between strategic signaling and chokepoint vulnerability, which is evident in the behavior of oil pricing, insurance markets, and maritime logistics. Empirical processes across several crisis events point to a consistent causal pathway: the presence of geopolitical signaling raises uncertainty levels → the level of uncertainty instigates AIS-based rerouting and insurance repricing → predictive behaviors enhance structural congestion and price fluctuations spur increased levels of geopolitical perception and future signaling motivations. This arrangement is in line with econometric evidence that indicates that geopolitical risk indices have a strong impact on the short-run dynamics of Brent crude volatility (Al-Majali et al., 2025). Thus, causality is non-linear, dynamic, and feedback-driven, as opposed to unidirectional.

Signaling associated with nuclei is also a tail-risk amplifier in an already highly sensitive systemic context. Although nuclear escalation in the Persian Gulf is quite unlikely, symbolic nuclear rhetoric has a significant impact on the perceived catastrophic risk in insurance, shipping, and derivatives markets. Behavioral risk theory has shown that decision-makers are systematic and structural in overweighting low-probability, high-impact events in the context of uncertainty, especially in an unstable geopolitical context (Tao et al., 2025). This is observed in oil futures markets by increasing volatility spreads and higher hedging intensity in Brent options prices. These perception changes are structurally magnified by system instability in chokepoint systems with low substitution capacity.

In general, the results affirm that the Strait of Hormuz is a reinforcing geopolitical-economic volatility amplifier, where oil prices, insurance premiums, and shipping behavior are mutually arrived at through recursive signal, perception, and structural constraint interactions. Systemic risk is an exogenous shock that is an endogenous consequence of constant feedback among geopolitical communication, anticipatory market functioning, and infrastructural focus.

5. DISCUSSION

The results of the current study provide a significant contribution to the current body of literature on maritime chokepoints by showing that the Strait of Hormuz is a coupled geopolitical-economic risk amplification mechanism, as opposed to a transit corridor or structurally determined bottleneck. Compared to traditional state-based approaches to understanding maritime security, evidence suggests that systemic instability arises as a result of recursive interactions among geopolitical signaling, institutional interpretation, and infrastructural concentration. This is in line with the complexity-based energy systems literature, which conceptualizes global oil markets as highly interconnected networks with nonlinear propagation and feedback amplification processes (Shu & Luo, 2025). This suggests that network interdependence results in systemic risk in the Strait, as opposed to being imposed externally.

Significant episodes of escalation, particularly the tanker accidents in 2019, have demonstrated that volatility transmission due to expectations, rather than the physical effects of disruption, dominates oil price dynamics. Intraday volatility peaks in the market were statistically significant in the case of Brent crude, although it did not suffer a sustained supply disruption, suggesting that this market reacts to

perceived geopolitical risk, not the actual loss of supply. This is in line with the oil market econometric literature, which shows that geopolitical risk is quickly included in crude oil pricing via forward-looking channels of expectation and risk premium adjustments (Wu et al., 2020). The Strait is then a high-frequency transmission node where the dominance of informational shocks in the short run over fundamental supply side processes prevails.

One of the major theoretical implications is that Strategic Signaling Theory cannot be applied alone because it does not consider the mediation of geopolitical information of geopolitics by institutions. The findings reveal that the signals produced by states are not directly transformed into the outcomes of the system but are fed through financialized maritime institutions, specifically insurance underwriting systems and freight pricing markets. Protection and Indemnity (P&I) maritime insurance markets have empirically demonstrated that an increase in the insurance cost by 20–300 percent during the escalation phases is an indicator of nonlinear repricing of risk in the case of uncertainty (Rezvani, 2020). This aligns with the findings of behavioral finance studies that uncertainty premiums are higher than the expected loss calculations because of the preference for anticipatory governance provisions that are inherent in world financial arrangements (Gammeltoft & Panibratov, 2024). Therefore, signaling is more of a channel of transmission of financial volatility and not a deterministic communication platform.

Structurally speaking, the results challenge the classical theory of chokepoint vulnerability, as they show that geographic concentration is a sufficient but not a necessary condition for systemic instability. The behavior of vessels using AISs is consistent in rerouting, forming a convoy, and speed variation when geopolitical tension erupts, even without physical interference. These results support the view that expectation formation and anticipatory optimization actively create vulnerability and not exogenous shocks. This interpretation is supported by the literature on maritime economics, where routing choices are made with reference to the anticipated risk-adjusted cost minimization, as opposed to spatial constraints (Vukić & Cerbán, 2022). This makes chokepoints dynamic risk situations and not structural bottlenecks.

The nonlinear effects of aggregation also provide evidence of AIS and are consistent with the theory of network science. Micro-level vessel route changes and transit timing changes are summed up to macro-level inefficiencies in global oil logistics, such as congestion effects and longer effective transit times. Network theory illustrates that loosely connected networks are overly sensitive to local perturbations, such that local perturbations on hub nodes cause cascading effects on the entire system (Zeng et al., 2025). This supports the concept of the Strait as a systemic amplifier of the topology of global energy networks.

Strategic signaling coupled with chokepoint vulnerability yields a recursive feedback mechanism of risk amplification, which can be observed in oil pricing, the insurance market, and maritime logistics behavior. The order empirically remains constant through various episodes of crisis: geopolitical signaling augments uncertainty → uncertainty augments AIS-based behavioral and financial reactions → structural congestion and volatility-augmented responses are returned to geopolitical signaling

incentives. This is consistent with the econometric results that geopolitical risk indices play a significant role in the dynamics of short-run Brent crude volatility (Zeng et al., 2025). Thus, causality is non-linear, dynamic, and feedback-based, as opposed to linear or exogenous.

Another amplification of systems is added through nuclear signaling, which activates tail-risk forms of cognitive systems over volatile systems of expectation. Even symbolic nuclear rhetoric can strongly impact the perception of risk, even though nuclear escalation in the Persian Gulf is extremely unlikely. Laboratory Behavioral risk theory proves that overweight agents make low-probability, high-impact decisions in times of uncertainty, especially in high-stakes geopolitical situations (Özdemir et al., 2025). This is reflected in the oil futures market in terms of the spread of volatility and amplified hedging in Brent options pricing. In chokepoint systems, these effects are structurally magnified because of the low ability to substitute.

Comprehensively, the evidence lends credence to the re-conceptualization of the Strait of Hormuz as a self-reinforcing volatility amplifier in geopolitical-economic terms that entails the joint formation of oil price, insurance pricing, and shipping behavior in recursive interactions of signaling, perception, and structural constraints. The Strait is not an external shock conduit but an endogenous instability generator that exists in world energy networks. This reframing adds to the literature on energy economics and maritime security because it shows that systemic risk is a product of internal processes, not external ones, generated by ongoing feedback between geopolitical communication, anticipatory market behavior, and infrastructural concentration.

6. CONCLUSION

This study shows that the Strait of Hormuz is a coupled geopolitical-economic system where strategic signaling, structural chokepoint constraints, and anticipatory market behavior are interdependent in causing recursive systemic risk. The data show that physical disruption is not the major source of risk in this corridor, but that it is perception-based responses that are fast-moving in terms of being spread by shipping, insurance, and energy pricing infrastructure. According to the literature on energy markets, oil price formation in geopolitically sensitive areas indicates the immediate addition of risk premiums instead of the delayed adjustment to physical alterations in supply (Yu et al., 2025). Likewise, studies of maritime networks establish that dense shipping routes enhance local uncertainty into global instability by being structurally interdependent and having a small ability to substitute routes (Razek et al., 2023). These results support the claim that the Strait is a systemic amplifier in which geopolitical communication is integrated into global economic signaling systems.

This research is relevant to the maritime security and energy economics literature as it redefines risk as a recursive process that is co-produced by the interaction between signaling systems and chokepoint vulnerability, as opposed to being an externally imposed shock. The findings indicate that low-probability, high-impact stories, including nuclear signaling, may significantly impact market sensitivity and prompt hedging behavior in the face of uncertainty (Usman et al., 2020). It helps to change linear, state-centric

conceptualizations of geopolitical risk to a systems-based approach, where perception, infrastructure, and communication constantly and mutually support each other. Therefore, the Strait of Hormuz can be conceptualized as not merely being a strategic maritime route but also as a risk transmission node in the world where geopolitical actions are methodically converted into economic instability via recursive feedback dynamics.

7. RECOMMENDATION

Based on the results of this study, a set of policy and analytical suggestions is outlined on how to enhance maritime security, mitigate the risk in the system, and improve stability in the Strait of Hormuz. The analysis reveals that the risk in the chokepoint systems is mostly perception-based and enhanced by global market interdependences, as opposed to being precipitated merely by physical disruptions. States and regional players must focus on effective strategic communication and enhanced maritime collaboration. The ambiguity in military signaling and political rhetoric can be minimized to reduce the likelihood of misinterpretation, and institutionalized cooperation (including joint monitoring and coordinated incident response systems) can be used to decrease informational gaps and reduce the risk of escalation in the area.

Meanwhile, actors in the energy market and shipping institutions must consider including geopolitical risk indicators in projections and prices. This would enhance sensitivity to risk and enable more precise responses to volatility caused by strategic signaling and regional instability. Finally, maritime governance frameworks should be strengthened to address emerging hybrid threats, such as cyberattacks, unmanned systems, and covert sabotage. An integrated approach that combines geopolitical analysis, security assessment, and market-based modelling is necessary, as fragmented policy responses are insufficient to manage the interconnected nature of the chokepoint risks.

Declarations

Data Availability

Data sharing is not applicable to this article, as no new data were generated or analyzed. This study is based exclusively on secondary data, including published academic literature, policy documents, and other publicly accessible sources.

Ethical Approval

This study did not involve human participants, animal subjects, or primary data collection; therefore, formal ethical approval was not required. The research is based exclusively on secondary data, including peer-reviewed academic literature and publicly available policy and industry reports. All sources have been appropriately cited in accordance with established standards of academic integrity and research ethics.

Informed Consent

Not applicable.

Author Contributions Statement

Ali Abdi Yusuf conceived the study, conducted the literature review, analyzed the findings, and wrote and revised the manuscript. Ali approved the final version and is accountable for all aspects of the work.

References

1. Ahmed, F., Sohag, K., Islam, M. M., & Hassan, M. K. (2025). Navigating turbulence: How do geopolitical risks and oil price shocks shape global equity markets? A GVAR approach. *Borsa Istanbul Review*, *25*(3), 449–467. https://doi.org/10.1016/j.bir.2025.01.016
2. Akbarzadeh, S., & Saba, A. (2025). China's Soft Power: Views from Saudi Arabia and the UAE. *Global Studies Quarterly*, *5*(1). https://doi.org/10.1093/isagsq/ksae090
3. Al-Majali, A., Alsarayreh, A., & Alqaralleh, H. (2025). Beyond Average Effects: Performance-Dependent Logistics Challenges in Emerging Asian Transportation Trade. *Logistics*, *10*(1), 2. https://doi.org/10.3390/logistics10010002
4. Antonilli, A. (2022). World Risk Society and Ulrich Beck's Manufactured Uncertainties. *Italian Sociological Review*, *12*(Special Issue 8), 907–930. https://doi.org/10.13136/isr.v12i8S.594
5. Astaíza-Gómez, J. G. (2025). Uncertainty, Risk, and Opaque Stock Markets. *International Journal of Financial Studies*, *13*(1). https://doi.org/10.3390/ijfs13010035
6. Atanassova, I., Bednar, P., Khan, H., & Khan, Z. (2025). Managing the VUCA environment: The dynamic role of organizational learning and strategic agility in B2B versus B2C firms. *Industrial Marketing Management*, *125*(September 2023), 12–28. https://doi.org/10.1016/j.indmarman.2024.12.008
7. Bednarski, L., Subramanian, N., Roscoe, S., & Blome, C. (2025). Geopolitical rivalry over strategically important industries: understanding the effects on global supply chain design. *Production Planning and Control*, *37*(6), 596–618. https://doi.org/10.1080/09537287.2025.2570203
8. Calzada, I., & Eizaguirre, I. (2026). EcoTechnoPolitics: Towards Planetary Thinking Beyond Digital–Green Twin Transitions. *Societies*, *16*(2), 1–42. https://doi.org/10.3390/soc16020057
9. Ćelić, J., Vukšić, M., Baždarić, R., & Cuculić, A. (2025). The Challenges of Cyber Resilience in the Maritime Sector: Addressing the Weak Awareness of the Dangers Caused by Cyber Threats. *Journal of Marine Science and Engineering*, *13*(4). https://doi.org/10.3390/jmse13040762
10. Chaziza, M., & Lutmar, C. (2025). Oman's Niche Diplomacy: Middle Power Strategies in a Shifting Middle East. *Social Sciences*, *14*(9), 1–16. https://doi.org/10.3390/socsci14090511
11. Chen, F., Tang, J., Chen, J., Yin, S., Du, L., Fu, G., Xu, F., & Liang, X. (2024). Understanding the information of shock effects between energy commodity prices and maritime freight rate. *Frontiers in Energy Research*, *12*(August), 1–15. https://doi.org/10.3389/fenrg.2024.1289327

12. Chi, X., Zheng, R., Chen, Y., & Xiao, G. (2025). Research on the volatility spillover effects of geopolitical conflict risks on international shipping and crude oil markets. *Frontiers in Marine Science*, *12*(October), 1–21. https://doi.org/10.3389/fmars.2025.1647599
13. Clavijo Mesa, M. V., Patino-Rodriguez, C. E., & Guevara Carazas, F. J. (2024). Cybersecurity at Sea: A Literature Review of Cyber-Attack Impacts and Defenses in Maritime Supply Chains. *Information (Switzerland)*, *15*(11). https://doi.org/10.3390/info15110710
14. Connelly, B. L., Certo, S. T., Reutzel, C. R., DesJardine, M. R., & Zhou, Y. S. (2025). Signaling Theory: State of the Theory and Its Future. *Journal of Management*, *51*(1), 24–61. https://doi.org/10.1177/01492063241268459
15. Dokas, I., Oikonomou, G., Panagiotidis, M., & Spyromitros, E. (2023). Macroeconomic and Uncertainty Shocks' Effects on Energy Prices: A Comprehensive Literature Review. *Energies*, *16*(3). https://doi.org/10.3390/en16031491
16. Emblemsvåg, M. S., & Emblemsvåg, J. (2025). A strategic- and tactical model for managing complex risks in social systems. *International Journal of Disaster Risk Reduction*, *128*(July), 105716. https://doi.org/10.1016/j.ijdrr.2025.105716
17. Erzurumlu, Y. O., Gozgor, G., Lau, C. K. M., Soliman, A. M., & Turkkan, M. (2025). The effects of geopolitical and political risks on corporate ESG practices. *Journal of Environmental Management*, *386*(October 2024), 125747. https://doi.org/10.1016/j.jenvman.2025.125747
18. Gammeltoft, P., & Panibratov, A. (2024). Emerging market multinationals and the politics of internationalization. *International Business Review*, *33*(3), 102278. https://doi.org/10.1016/j.ibusrev.2024.102278
19. Gnangnon, S. K. (2022). Effect of Structural Economic Vulnerability on the Participation in International Trade. *Journal of Risk and Financial Management*, *15*(9). https://doi.org/10.3390/jrfm15090417
20. Gong, W., Li, Z., & Tang, J. (2026). Impact of risk perception on emergency information seeking behavior: a meta-analysis. *Frontiers in Psychology*, *16*(January). https://doi.org/10.3389/fpsyg.2025.1646584
21. Guo, L., Yu, F., Sui, C., & Yang, M. (2026). Country-Level Vulnerability in Maritime Bulk Commodity Supply Chains: An Integrated Framework for Identification, Monitoring, and Extrapolation. *Systems*, *14*(2), 1–39. https://doi.org/10.3390/systems14020120
22. He, Z., & Niu, J. (2018). The effect of economic policy uncertainty on bank valuations. *Applied Economics Letters*, *25*(5), 345–347. https://doi.org/10.1080/13504851.2017.1321832
23. Healy, N., Stephens, J. C., & Malin, S. A. (2019). Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains. *Energy Research and Social Science*, *48*(September 2018), 219–234. https://doi.org/10.1016/j.erss.2018.09.016
24. Johnson, J. (2021). 'Catalytic nuclear war' in the age of artificial intelligence & autonomy: Emerging military technology and escalation risk between nuclear-armed states. *Journal of Strategic Studies*,

00(00), 1–41. https://doi.org/10.1080/01402390.2020.1867541

25. Jugović, A., Sirotić, M., Jugović, T. P., & Žgaljić, D. (2025). Green Shipping Corridors: A Bibliometric Analysis of Policy, Technology, and Stakeholder Collaboration. *Applied Sciences (Switzerland)*, *15*(6). https://doi.org/10.3390/app15063304
26. Kertzer, J. D., Rathbun, B. C., & Rathbun, N. S. (2020). The Price of Peace: Motivated Reasoning and Costly Signaling in International Relations. *International Organization*, *74*(1), 95–118. https://doi.org/10.1017/S0020818319000328
27. Li, Y., Xia, X., Wang, Y., & Huang, Q. (2026). Geopolitical Risk and Shipping Supply Chain Resilience: Systemic Characteristics, Impact Mechanisms, and the Security of Logistics Nodes. *Systems*, *14*(4). https://doi.org/10.3390/systems14040427
28. Liu, J., Song, Q., Qi, Y., Rahman, S., & Sriboonchitta, S. (2020). Measurement of systemic risk in global financial markets and its application in forecasting trading decisions. *Sustainability (Switzerland)*, *12*(10). https://doi.org/10.3390/SU12104000
29. López, C., Morales-Contreras, M. F., Langella, I. M., & Alonso-Monge, J. (2025). Modeling supply chain disruptions due to geopolitical Reasons: A systematic literature review. *Transportation Research Part E: Logistics and Transportation Review*, *202*(July 2024). https://doi.org/10.1016/j.tre.2025.104290
30. McMillan, L., Pescaroli, G., Gordon, M., Maraschini, M., Torresan, S., Palma-Oliveira, J., Rosa, B., Sarroeira, A., Trump, B. D., & Linkov, I. (2026). High impact low probability events: research landscape and future opportunities. *Natural Hazards*, *122*(9), 1–25. https://doi.org/10.1007/s11069-026-08107-8
31. Meza, A., Ari, I., Sada, M. Al, & Koç, M. (2022). Disruption of maritime trade chokepoints and the global LNG trade: An agent-based modeling approach. *Maritime Transport Research*, *3*(May), 100071. https://doi.org/10.1016/j.martra.2022.100071
32. Min, H. (2022). Examining the Impact of Energy Price Volatility on Commodity Prices from Energy Supply Chain Perspectives. *Energies*, *15*(21). https://doi.org/10.3390/en15217957
33. Mišković, D., & Wang, H. (2025). Exploring the Impact of the Maritime Regulatory Framework on the Barrier System in Ship Operations. *Journal of Marine Science and Engineering*, *13*(7), 1–19. https://doi.org/10.3390/jmse13071361
34. Moravej, S., Jafarpanah, I., Kazemi, Z., & Hesabi, F. (2026). Outsourcing strategies for pilotage and towage Operations: A grounded theory approach. *Case Studies on Transport Policy*, *23*(November 2025). https://doi.org/10.1016/j.cstp.2025.101691
35. Murphy, S. P., & McGandy, M. (2026). Localisation and Locally Led Development in the Post-consensus Era: Transformation, Stagnation, or Annihilation? *European Journal of Development Research*, 191–215. https://doi.org/10.1057/s41287-025-00734-4
36. Nassary, E. K., Magubika, A. J., Mwampashi, L. L., Fukah, F. K., Kahangwa, C. A., & Tryphone, G. M. (2025). Transitioning to clean energy and opportunities for developing countries. *Energy Strategy Reviews*, *62*(July), 101909. https://doi.org/10.1016/j.esr.2025.101909

37. Okutan, P., & Otay, E. N. (2025). Climate Change Risk Perception, Adaptive Capacity and Psychological Distance in Urban Vulnerability: A District-Level Case Study in Istanbul, Türkiye. *Sustainability (Switzerland)*, *17*(12), 1–29. https://doi.org/10.3390/su17125358
38. Özdemir, L., Vurur, N. S., Ozen, E., Świecka, B., & Grima, S. (2025). Volatility Modeling of the Impact of Geopolitical Risk on Commodity Markets. *Economies*, *13*(4). https://doi.org/10.3390/economies13040088
39. Pang, M., Huo, C., Wang, X., & Malik, T. H. (2026). The strategic interplay of market orientation and digital transformation: Empirical insights from textual analysis. *Long Range Planning*, *59*(1), 102604. https://doi.org/10.1016/j.lrp.2026.102604
40. Petropoulos, F., Akkermans, H., Aksin, O. Z., Ali, I., Babai, M. Z., Barbosa-Povoa, A., Battaïa, O., Besiou, M., Boysen, N., Brammer, S., Brandon-Jones, A., Briskorn, D., Browning, T. R., Buijs, P., Centobelli, P., Chiarini, A., Cousins, P., Cudney, E. A., Davies, A., … Zheng, T. (2026). Operations & supply chain management: principles and practice. *International Journal of Production Research*, *64*(1), 330–513. https://doi.org/10.1080/00207543.2025.2555531
41. Pratson, L. F. (2023). Assessing impacts to maritime shipping from marine chokepoint closures. *Communications in Transportation Research*, *3*(December 2022), 100083. https://doi.org/10.1016/j.commtr.2022.100083
42. Prussi, M., Scarlat, N., Acciaro, M., & Kosmas, V. (2021). Potential and limiting factors in the use of alternative fuels in the European maritime sector. *Journal of Cleaner Production*, *291*, 125849. https://doi.org/10.1016/j.jclepro.2021.125849
43. Razek, N., Galvani, V., Rajan, S., & McQuinn, B. (2023). Can U.S. strategic petroleum reserves calm a tight market exacerbated by the Russia–Ukraine conflict? *Resources Policy*, *86*(PB), 104062. https://doi.org/10.1016/j.resourpol.2023.104062
44. Rezvani, B. (2020). Russian foreign policy and geopolitics in the Post-Soviet space and the Middle East: Tajikistan, Georgia, Ukraine and Syria. *Middle Eastern Studies*, *56*(6), 878–899. https://doi.org/10.1080/00263206.2020.1775590
45. Roberts, D. B. (2025). The Gulf's evolving security mosaic: balancing the manifest retrenchment and latent influence of the United States. *International Affairs*, *101*(6), 2193–2214. https://doi.org/10.1093/ia/iiaf183
46. Runganga, D., Bharadwaj, B., Cabalu, H., & Ashworth, P. (2025). Towards global cooperation in securing critical minerals: Game theory analyses of policy discourses from the United States, the European Union, South Africa and Australia. *Resources Policy*, *111*(November), 105792. https://doi.org/10.1016/j.resourpol.2025.105792
47. Saidi, M., Esmaeildoost, F., Khankan, R., Masarani, H., & Toyasaki, F. (2026). Logistical agility at the Strait of Hormuz: A framework for managing sustained geopolitical disruption risks in global supply chains. *Transport Policy*, *183*(April), 104168. https://doi.org/10.1016/j.tranpol.2026.104168
48. Shepard, J. U., & Pratson, L. F. (2020). Maritime piracy in the Strait of Hormuz and implications of energy export security. *Energy Policy*, *140*, 1–32. https://doi.org/10.1016/j.enpol.2020.111379

49. Shu, W., & Luo, H. (2025). Forecasting crude oil futures volatility with extreme-value information and dynamic jumps. *Frontiers in Environmental Economics*, *4*. https://doi.org/10.3389/frevc.2025.1511074
50. Sin, G. (2026). Applying Extreme Value Theory to a Century of Ammonium Nitrate Disasters: Persistent Safety Risks in Chemical Supply Chains. *Risk Analysis*, *46*(3), 1–13. https://doi.org/10.1111/risa.70194
51. Sinani, E., Hobdari, B., Brandl, K., & Gammelgaard, J. (2026). Caught in the crossfire: Multinational enterprises in the era of geopolitical tensions. *International Business Review*, *35*(4). https://doi.org/10.1016/j.ibusrev.2026.102590
52. Tao, M., Che, S., Qi, L., Wu, L., & Saadaoui, J. (2025). Global oil trading networks: Structural patterns and geopolitical risks. *Energy Economics*, *151*(October), 108965. https://doi.org/10.1016/j.eneco.2025.108965
53. Tsantis, A., Mangan, J., & Palacin, R. (2026). *insights into network adaptability and supply chain resilience*.
54. Ünlü, H. (2024). Deterrence in Inter-State Communication: International Signaling Strategies. *Erciyes İletişim Dergisi*, *11*(2), 441–459. https://doi.org/10.17680/erciyesiletisim.1444923
55. Usman, S. M., Bukhari, F. A. S., You, H., Badulescu, D., & Gavrilut, D. (2020). The Effect and Impact of Signals on Investing Decisions in Reward-Based Crowdfunding: A Comparative Study of China and the United Kingdom. *Journal of Risk and Financial Management*, *13*(12), 1–20. https://doi.org/10.3390/jrfm13120325
56. Verschuur, J., Lumma, J., & Hall, J. W. (2025). Systemic impacts of disruptions at maritime chokepoints. *Nature Communications* , *16*(1), 1–13. https://doi.org/10.1038/s41467-025-65403-w
57. von Malmborg, F. (2024). Strategies and Impacts of Policy Entrepreneurs: Ideology, Democracy, and the Quest for a Just Transition to Climate Neutrality. *Sustainability (Switzerland)* , *16*(12). https://doi.org/10.3390/su16125272
58. Vukić, L., & Cerbán, M. del M. (2022). Economic and environmental competitiveness of container shipping on alternative maritime routes in the Asia-Europe trade flow. *Maritime Transport Research*, *3*(May). https://doi.org/10.1016/j.martra.2022.100070
59. Wang, X., Du, D., & Peng, Y. (2024). Assessing the Importance of the Marine Chokepoint: Evidence from Tracking the Global Marine Traffic. *Sustainability (Switzerland)*, *16*(1). https://doi.org/10.3390/su16010384
60. Wu, C., Wang, X., Luo, S., Shan, J., & Wang, F. (2020). Influencing factors analysis of crude oil futures price volatility based on mixed-frequency data. *Applied Sciences (Switzerland)*, *10*(23), 1–32. https://doi.org/10.3390/app10238393
61. Yang, H., Liu, C., Cao, Y., Shu, Y., Gan, L., Liu, Z., & Yang, Z. (2026). Dynamic resilience assessment of global shipping networks against cascading effects: An AIS data-driven complex network analysis. *Sustainable Horizons*, *18*(February), 100184. https://doi.org/10.1016/j.horiz.2026.100184

62. Yi, Y., Sun, Z. Y., Fu, B. A., Tong, W. Y., & Huang, R. S. (2025). Accelerating Towards Sustainability: Policy and Technology Dynamic Assessments in China's Road Transport Sector. *Sustainability (Switzerland)*, *17*(8). https://doi.org/10.3390/su17083668
63. Yu, C., Jiao, D., Wei, Y., & Wang, Q. (2025). How Does Global Supply Chain Pressure Affect Oil Prices in Futures Markets? *Sustainability (Switzerland)*, *17*(16), 1–21. https://doi.org/10.3390/su17167241
64. Zardoshti Zadeh Yazdi, M., Meyer, J. C., & Walther, G. (2026). Multi-objective supply chain optimization of renewable energy carrier imports for Europe. *Applied Energy*, *415*(April). https://doi.org/10.1016/j.apenergy.2026.127884
65. Zeng, Z., Wang, N., Xu, D., & Chen, R. (2025). Cascading Failure Modeling and Resilience Analysis of Coupled Centralized Supply Chain Networks Under Hybrid Loads. *Systems*, *13*(9), 1–40. https://doi.org/10.3390/systems13090729
66. Zhai, L., & Lee, J. E. (2024). Investigating Vulnerability, Adaptation, and Resilience: A Comprehensive Review within the Context of Climate Change. *Atmosphere*, *15*(4), 1–19. https://doi.org/10.3390/atmos15040474