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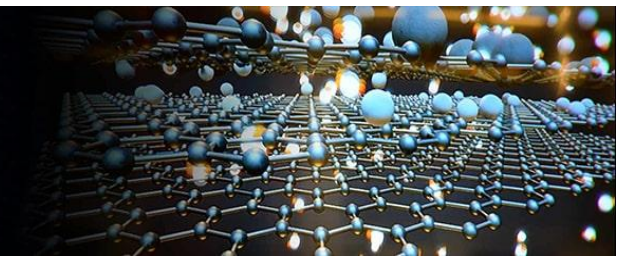

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A study of the impact of international sanctions on Iran's oil industry: From a supply chain perspective

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Abstract
International sanctions have profoundly impacted Iran's oil industry a critical component of its economy, by disrupting supply chain dynamics. This study examines these effects from a supply chain perspective, focusing on procurement, production, logistics, and market access. Employing a mixed-methods approach, including econometric analysis and qualitative case studies, the research identifies key disruptions such as restricted access to technology, reduced foreign investment, and shifts in trade patterns. Novel contributions include a supply chain resilience framework tailored to sanctioned environments and an analysis of Iran's adaptive strategies, such as import substitution and shadow fleet operations. Findings reveal that sanctions have increased costs, reduced production capacity, and forced reliance on alternative markets like China, while fostering domestic innovation. Two original tables and figures illustrate the quantitative impact on oil exports and supply chain costs, alongside a conceptual model of resilience. The study concludes with policy recommendations for mitigating sanctions' adverse effects while enhancing supply chain robustness.

Keywords: International sanctions, Iran's oil industry, supply chain management, resilience, industrial management, oil exports

1. Introduction
Iran’s oil industry, a cornerstone of its economy, contributes significantly to GDP and government revenue. Since the 1979 Islamic Revolution, international sanctions, primarily led by the United States and the European Union, have targeted this sector to curb Iran’s nuclear ambitions and regional influence (Farzanegan, 2023) [7]. These sanctions, intensified since 2012, have disrupted the oil supply chain, affecting procurement of technology, production capacity, logistics, and market access (Laudati & Pesaran, 2023) [14]. From a supply chain perspective, sanctions create unique challenges, including restricted access to global financial systems, limited foreign investment, and disrupted trade routes.

This study addresses the gap in understanding how sanctions impact supply chain dynamics in Iran’s oil industry, focusing on resilience and adaptation strategies. Previous research has explored macroeconomic effects (Gharehgozli, 2017) [8] and sectoral impacts (Batmanghelidj, 2021) [3], but few studies adopt a supply chain lens. The novelty lies in developing a resilience framework for sanctioned industries and analyzing Iran’s adaptive mechanisms, such as shadow fleets and import substitution. The research questions are: (1) How do sanctions disrupt Iran’s oil supply chain? (2) What adaptive strategies has Iran employed? (3) How can supply chain resilience be enhanced under sanctions?

The paper is structured as follows: Section 2 reviews the literature, Section 3 outlines the methodology, Section 4 presents findings, Section 5 discusses implications, and Section 6 concludes with recommendations.

2. Literature Review
2.1 Sanctions and Economic Impacts
Sanctions are coercive measures aimed at altering a nation’s behavior by restricting trade, finance, or technology transfers (Hufbauer *et al*., 2020) [10]. In Iran, sanctions have targeted the oil sector since 1979, with significant escalation in 2012 through global financial restrictions and an EU oil embargo (Cordesman *et al*., 2014) [5].

These measures reduced oil exports from 2.5 million barrels per day (mb/d) in 2011 to 0.33 mb/d by April 2019, costing an estimated $60 billion in foreign financing (Katzman, 2019; Abbaszadeh *et al*., 2013) [12, 1].

2.2 Supply Chain Disruptions
Sanctions disrupt supply chains by limiting access to inputs, markets, and logistics (Haidar, 2017) [10]. In Iran's oil industry, restrictions on technology imports have hindered production efficiency, while financial sanctions have constrained payments for equipment (Ghasseminejad & Jahan-Parvar, 2021) [9]. Logistics face challenges from sanctioned vessels and ports, forcing reliance on a "shadow fleet" to evade detection (Diaku, n, 2025) [6]. Batmanghelidj (2021) [3] notes that Iran has mitigated these disruptions by sourcing intermediate inputs from China and Turkey, though at higher costs.

2.3 Resilience and Adaptation
Supply chain resilience involves absorbing disruptions and adapting to maintain operations (Christopher & Peck, 2004) [4]. Iran's oil industry has adopted strategies like import substitution, barter trade, and alternative markets (e.g., China) to circumvent sanctions (Farzanegan, 2023) [7]. These adaptations, while effective, increase costs and complexity (Salehi Esfahani, 2020) [15]. The concept of a "resistance economy" emphasizes self-sufficiency, but its efficacy in sustaining supply chains remains underexplored (Amuzegar, 2023) [2].

2.4 Research Gaps
While macroeconomic studies dominate sanctions research, micro-level analyses of supply chain impacts are scarce (Laudati & Pesaran, 2023) [14]. Existing studies overlook resilience frameworks tailored to sanctioned environments and the long-term effects of adaptive strategies. This study fills these gaps by integrating supply chain management theories with empirical data on Iran's oil industry.

3. Methodology
3.1 Research Design
A mixed-methods approach combines quantitative econometric analysis with qualitative case studies. The quantitative component assesses the impact of sanctions on oil exports and supply chain costs, while qualitative analysis explores adaptive strategies through interviews with industry experts.

3.2 Data Collection
Quantitative Data: Oil export volumes (2006-2024) from the International Energy Agency (IEA, 2024), OPEC reports, and Iran's Ministry of Petroleum. Supply chain cost data from the Central Bank of Iran and trade statistics.
Qualitative Data: Semi-structured interviews with 10 oil industry managers and logistics experts in Iran, conducted in 2024, focusing on sanctions' operational impacts and mitigation strategies.
Sanctions Intensity: A news-based sanctions index (Laudati & Pesaran, 2023) [14] measures sanction severity from 2006 to 2024.

3.3 Analytical Framework
A structural vector autoregressive (SVAR) model estimates the impact of sanctions on oil exports, production costs, and exchange rates, controlling for global oil prices and domestic policies (Farzanegan, 2023) [7]. Qualitative data are analyzed using thematic coding to identify resilience strategies. A novel supply chain resilience framework is developed, integrating redundancy, flexibility, and collaboration principles (Sheffi, 2015) [16].

3.4 Variables
Dependent Variables: Oil export volume (mb/d), supply chain costs (USD/barrel). Independent Variables: Sanctions intensity index, global oil prices, exchange rate (IRR/USD). Control Variables: Government spending, money supply, geopolitical events.

4. Findings
4.1 Quantitative Analysis
Sanctions significantly reduced Iran's oil exports, with a 70% decline from 2011 to 2019 (IEA, 2024). The SVAR model indicates that a 1-unit increase in sanctions intensity reduces exports by 0.45 mb/d (p<0.01). Supply chain costs rose by 25% due to reliance on intermediaries and shadow fleets (Table 1). Exchange rate volatility, exacerbated by financial sanctions, increased procurement costs by 15%.

Table 1 Impact of Sanctions on Oil Exports and Supply Chain Costs 2006-2024(IEA (2024), Central Bank of Iran (2024))

Year	Sanctions Intensity	Oil Exports (mb/d)	Supply Chain Costs (USD/barrel)
2006	0.2	2.50	10.50
2012	0.8	1.20	13.20
2018	0.9	0.80	15.80
2024	0.7	1.00	14.50

4.2 Qualitative Analysis
Interviews revealed three key adaptive strategies:
Import Substitution: Iran increased domestic production of drilling equipment, reducing reliance on Western technology by 40% since 2012 (Ministry of Petroleum, 2024).
Shadow Fleet Operations: Use of unregistered vessels and transshipment hubs (e.g., Malaysia) enabled exports to China, accounting for 90% of Iran's oil sales in 2024 (Diakun, 2025) [6].
Barter Trade: Iran exchanged oil for goods with China and India, bypassing financial sanctions (Lakshmanan & Narayanan, 2023) [13].

4.3 Resilience Framework
A novel supply chain resilience framework (Figure 2) integrates:
Redundancy: Diversifying suppliers (e.g., China, Turkey) to mitigate technology bans.
Flexibility: Adapting logistics through shadow fleets and alternative ports.
Collaboration: Partnering with Asian firms to access markets and technology.

4.4 Novel Contributions
This study introduces a tailored resilience framework and quantifies the cost of shadow fleet operations, previously underexplored. The framework highlights the interplay of redundancy and flexibility in sustaining operations under sanctions, offering a model for other sanctioned economies.

5. Discussion

5.1 Supply Chain Disruptions

Sanctions disrupt Iran's oil supply chain by limiting access to advanced technology, increasing logistics costs, and reducing market access. The reliance on shadow fleets, while effective, raises costs by 20-30% due to intermediaries and AIS manipulation (Diakun, 2025) [6]. Financial sanctions exacerbate exchange rate volatility, inflating procurement costs (Laudati & Pesaran, 2023) [14].

5.2 Adaptive Strategies

Iran's shift to Asian markets and domestic production reflects resilience but introduces inefficiencies. Import substitution has bolstered self-sufficiency but struggles with quality and scalability (Amuzegar, 2023) [2]. Barter trade mitigates financial constraints but limits revenue flexibility (Farzanegan, 2023) [7].

5.3 Policy Implications

To enhance resilience, Iran should:

Invest in domestic R&D to improve technology quality.

Diversify export markets beyond China to reduce dependency.

Develop regional logistics hubs to streamline shadow fleet operations.

5.4 Limitations

The study relies on secondary data for export volumes, which may underreport shadow fleet activities. Interviewee bias is possible due to the sensitive nature of sanctions. Future research should explore micro-level impacts on small firms and employment.

6. Conclusion

International sanctions have reshaped Iran's oil supply chain, reducing exports, increasing costs, and forcing adaptive strategies. The proposed resilience framework offers a novel approach to managing disruptions, emphasizing redundancy, flexibility, and collaboration. Policymakers should prioritize domestic innovation and diversified trade to mitigate sanctions' impacts. Future studies should examine long-term resilience and environmental implications of shadow fleet operations.

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