

Cost Asymmetry, Redundancy Underinvestment, and the Unintended Consequences of Environmental Regulation: Evidence from Indian Aviation

Tarun Gangadhara

Tarungan00@gmail.com

John Nash Thesis Fellowship

Research Article

Keywords: cost asymmetry, regulatory externality, system fragility, aviation economics, environmental regulation

Posted Date: May 15th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9571939/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

This paper examines the relationship between firm-level cost asymmetry, endogenous system fragility, and regulatory design in a price-elastic transport market. Using IndiGo (InterGlobe Aviation Ltd.) as the empirical setting, we develop a formal model linking operational slack to both cost per available seat kilometre (CASK) and the probability of major service disruption. Three contributions emerge. First, we demonstrate formally that private incentives to minimise operational costs generate underinvestment in system redundancy relative to the social optimum, with the externality quantified at approximately INR 35–110 crore for the December 2025 operational crisis, in which 4,500 flights were cancelled and approximately one million passengers were disrupted. Second, applying Shavell's (1984) liability-regulation framework, we show that mandatory minimum scheduling slack weakly dominates enhanced compensation liability as a regulatory instrument under asymmetric information about the firm's disruption probability. Third, we derive that India's forthcoming sustainable aviation fuel mandate, intended to correct carbon emissions externalities, generates an unintended market structure externality through heterogeneous firm-level cost impacts: the mandate compresses margins proportionally more at high-cost carriers, potentially accelerating their exit and raising market concentration beyond the environmental-welfare optimum. Sensitivity analysis confirms that mandatory slack is welfare-positive under all but the most conservative disruption frequency assumptions. The results suggest that welfare-optimal regulatory design in highly concentrated transport markets must address both disruption externalities and the unintended market structure effects of environmental mandates simultaneously.

JEL Classification: L93 (Air Transportation); L51 (Economics of Regulation); D62 (Externalities); L13 (Oligopoly and Other Imperfect Markets); Q58 (Environmental Economics: Government Policy); D61 (Welfare Economics)

1 Introduction

This paper is concerned with a regularity that appears in concentrated, price-elastic transport markets: private cost minimisation generates welfare-improving consumer surplus at the same time as it generates systemic fragility that imposes uncompensated costs on consumers when shocks occur. The policy question is whether, and how, regulation can internalise the fragility externality without eliminating the cost competition that generates the consumer surplus.

IndiGo (InterGlobe Aviation Ltd.) provides a sharply observed empirical context. The carrier holds approximately 65% of India's domestic aviation market as of mid-2025 (DGCA, 2025). Its cost per available seat kilometre (CASK) of INR 4.96 in FY2024 is approximately INR 2–3 below its nearest rival, a gap produced by a system of cost minimisation mechanisms: tri-ramp ground operations, electronic flight bag adoption, slimline seating, and closed-loop digitisation (InterGlobe Aviation Ltd., 2024). In a market where consumers regularly substitute between air and subsidised rail, this cost advantage is the dominant competitive mechanism.

In December 2025, IndiGo cancelled over 4,500 flights, disrupted approximately one million passengers, and incurred direct compensation liabilities of INR 24 crore (Times of India/NDTV, 2025). We argue that this event is not incidental to IndiGo's cost model; it is a predictable consequence of it. The scheduling tightness, fleet homogeneity, and process standardisation that generate the CASK advantage also reduce the system's slack, increasing the probability and severity of cascading failures under exogenous shocks. This is the efficiency-resilience trade-off, stated precisely: the same architectural properties that minimise expected cost in normal operations also maximise the damage from disruption events.

The welfare implication follows from Shavell (1984). When disruption costs are partially externalized, private optimal slack is below the socially optimal level. We estimate that IndiGo's INR 24 crore in direct compensation covered only 18–41% of the social disruption cost, which we place at INR 59–134 crore when passenger time costs are included. The externality gap is the mechanism of underinvestment.

A second regulatory question concerns the forthcoming sustainable aviation fuel (SAF) mandate. India's Ministry of Civil Aviation has notified SAF blending requirements rising to 5% by 2030, aligned with the Carbon Offsetting and Reduction Scheme for International Aviation (MoCA, 2025). This mandate is designed to correct a carbon emissions externality. We show that it simultaneously generates an unintended market structure externality: because the mandate imposes a uniform absolute cost increase on an industry with pre-existing cost asymmetries, it compresses margins proportionally more at high-cost carriers, potentially accelerating their exit and increasing market concentration. A carbon regulation may therefore produce an unintended competition policy outcome.

1.1 Research Questions

This paper examines three interrelated questions. First, does firm-level cost asymmetry in a price-elastic market translate into durable market share under exogenous regulatory cost shocks? Second, do private incentives to minimise operational costs generate negative externalities through underinvestment in system redundancy, and how large is this externality? Third, what regulatory instrument best internalises the disruption externality, and does the environmental SAF mandate generate an unintended market structure externality that requires separate policy attention?

1.2 Contributions

This paper contributes to the industrial organisation literature by formally modelling how firm-level cost asymmetries interact with endogenous fragility risk and exogenous regulatory shocks in a price-elastic transport market. It extends Shavell's (1984) liability-regulation framework to the operational slack context, deriving the conditions under which mandatory minimum scheduling requirements dominate enhanced compensation liability. It contributes to the regulatory economics literature by quantifying the welfare gap between private and social disruption costs and by formally characterising the unintended market structure effects of environmental mandates in industries with pre-existing cost asymmetries, in the tradition of Fischer and Newell (2008) on multi-objective environmental policy.

2 Related Literature

This paper connects four streams of existing research. The first is the industrial organisation economics of airline markets. Morrison and Winston (1987, 1995) established that airline deregulation produces substantial consumer welfare gains through fare competition, with low-cost carriers as the primary mechanism. Borenstein (1989) showed that hub dominance confers persistent market power in concentrated markets, with fare premia attributable to market share rather than cost efficiency alone. The Indian domestic market differs from the U.S. deregulated setting in that cost competition rather than hub dominance drives concentration: IndiGo's 65% share is achieved at fare levels constrained by rail substitutability rather than supported by hub-and-spoke connectivity. Baumol, Panzar, and Willig's (1982) contestable markets framework is relevant as a theoretical benchmark: Indian aviation is contestable in theory (no slot scarcity at secondary airports) but exhibits entry barriers in practice (Table 3) consistent with Bain's (1956) absolute cost advantage classification.

The second stream is the regulatory economics of externalities and instrument choice. Shavell (1984) derives the conditions under which liability rules dominate safety regulation and vice versa, with the key finding that mandatory regulation is preferred when the regulator cannot observe the firm's private cost or probability of harm. We apply this framework directly to the operational slack context in Section 7.2. Laffont and Tirole (1993) provide the information-theoretic foundations: when the firm has private information about its disruption probability, liability-based instruments require costly information revelation that mandatory standards avoid.

The third stream is the economics of multi-objective environmental regulation. Fischer and Newell (2008) show that when a single instrument (a carbon price or mandate) must address multiple market failures simultaneously, the second-best instrument design involves trade-offs between competing objectives. Requate (2005) surveys how dynamic incentive effects of environmental policy instruments depend on industry cost structure and competitive conditions. Our finding that the SAF mandate generates a market structure externality alongside its intended carbon externality correction is a direct application of the Fischer-Newell framework to the aviation context.

The fourth stream is the network economics of systemic fragility. Allen and Gale (2000) demonstrate in the financial context that tightly coupled networks amplify shocks non-linearly, with the cascade magnitude depending on network topology and node connectivity. Watts (2002) formalises cascade thresholds on random networks: a cascade occurs when a local failure exceeds the threshold load capacity of connected nodes, propagating globally. We apply this framework to the airline scheduling network in Section 6.2: IndiGo's 1,800 daily scheduling slots constitute a network with high node connectivity and minimal threshold margin (slack), producing the cascade conditions that Watts identifies.

3 Industry Context and Data

3.1 Market Structure

The Indian domestic aviation market is highly concentrated and price-elastic. IndiGo's market share of approximately 65% produces a Herfindahl-Hirschman Index (HHI) of approximately 4,600 based on reported carrier shares as of mid-2025, well above the 2,500 threshold conventionally used to classify markets as highly concentrated (DGCA, 2025). The market has consolidated significantly since 2019 through the exit of Jet Airways and the merger of Vistara into Air India, reducing the number of economically viable full-service competitors to one: the Tata Group-controlled Air India, which holds approximately 24% of the domestic market following the Vistara merger.

Despite this concentration, fares remain acutely constrained by rail substitutability. Indian Railways operates subsidised long-distance fares on the major corridors that constitute IndiGo's highest-frequency routes. Fare elasticity in the INR 3,000–8,000 segment relevant to IndiGo's price-point is estimated at -1.5 to -2.5 by CAPA India (2024), among the highest of any large civil aviation market globally. In this context, a carrier's ability to sustain the lowest structural CASK is not a competitive advantage in the usual sense; it is a necessary condition for profitable operation in the segments driving demand growth.

3.2 Data Sources and Scope

The empirical analysis draws on IndiGo's Annual Reports for FY2019 through FY2024 (InterGlobe Aviation Ltd., 2024) and the Business Responsibility and Sustainability Report for FY2024-25 (InterGlobe Aviation Ltd., 2025) for all IndiGo-specific financial and operational metrics. CASK and RASK figures are in nominal INR, net of fuel hedging effects where disclosed. Market share and on-time performance data are from DGCA monthly publications (DGCA, 2025). Competitor CASK estimates are derived from analyst consensus, specifically CAPA India (2024) and Jefferies India (2024), and should be treated as directional approximations. The December 2025 disruption data are from published press reporting (Times of India/NDTV, 2025); root-cause analysis has not been publicly disclosed by IndiGo at the time of writing. Table 1 presents key performance indicators across the analytical window. The complete panel dataset, variable definitions, source codes, and derivation notes for all CASK estimates are given in Online Resource 2.

Table 1
IndiGo Financial and Operational Performance Indicators, FY2019-FY2024

Metric	FY2019	FY2021 (COVID shock)	FY2022	FY2023	FY2024	Change FY2023- FY2024
CASK (INR per ASK)	4.47	5.92	6.81	5.36	4.96	-7.5%
RASK (INR per ASK)	3.92	3.15	5.72	5.61	5.48	-2.3%
RASK-CASK Spread (INR)	-0.55	-2.77	-1.09	+ 0.25	+ 0.52	+ 108%
Load Factor (%)	87.3	54.2	80.5	85.9	87.4	+ 1.7 pp
Domestic Market Share (%)	47.5	53.1	56.8	61.2	~ 64.7	+ 3.5 pp
CO ₂ e per ASK (g)	~ 74.2	N/A	~ 70.1	~ 64.8	61.7	-4.8%
<i>Notes: CASK = Cost per Available Seat Kilometre; RASK = Revenue per Available Seat Kilometre; pp = percentage points. CASK and RASK are net of fuel hedging effects where disclosed. COVID disruption visible in FY2021. The positive RASK-CASK spread from FY2023 onwards is the central empirical fact motivating the cost asymmetry analysis. Sources: InterGlobe Aviation Ltd. (2024); DGCA (2025); InterGlobe Aviation Ltd. (2025).</i>						

4 Cost Minimisation Architecture

4.1 The Four Cost Minimisation Levers

IndiGo's CASK advantage is produced by four cost minimisation levers operating in parallel. We denote these as the efficiency vector $\{\epsilon_i\}$ in the formal model of Section 5. The levers and their quantified CASK contributions are presented in Table 2, with all savings expressed as ranges to reflect ATF price sensitivity (INR 80–120 per kilogram) and adoption-rate uncertainty.

Slimline seating removes 900-1,080 kg of structural weight per aircraft, yielding a 1.2–1.4% trip-fuel reduction on standard 1,000 nm missions per the Airbus fuel-weight proportionality framework (Airbus, 2019). At fleet scale, this represents INR 280–490 crore per year. Electronic flight bag adoption removes approximately 40 kg of paper documentation per aircraft, adding INR 11–23 crore annually. Tri-ramp ground operations recover 25–120 block-hours per day depending on adoption scope, at an estimated contribution of INR 37–176 crore annually. The neo fleet multiplier (A320neo and A321neo aircraft, delivering 15–20% fuel efficiency improvement over CEO variants) amplifies all prior levers proportionally. All estimates assume linear weight-to-fuel proportionality; actual savings are convex and route-dependent.

Table 2
CASK Decomposition: Cost Minimisation Levers and Quantified Ranges (FY2024-2030)

Cost Minimisation Lever	Mechanism	Quantified Impact (Range)	Annual Saving (INR Crore)	CASK Effect (basis points)
Slimline Seats (15 kg to 9–10 kg x 180 seats)	Weight to Fuel	900-1,080 kg removed per aircraft; 1.2–1.4% trip-fuel saving on 1,000 nm mission	280–490	-2.0 to -4.0
EFB / Less-Paper Cockpit (~ 40 kg)	Weight to Fuel	~ 0.05% fuel per sector; ~7–8 kL saved per day (300+ aircraft fleet)	11–23	-0.3 to -0.6
Tri-Ramp Deplaning Conservative (1/3 fleet, major metros)	Time to Utilisation	~ 25–30 block-hours per day; 100 aircraft x 4 turns x 4 minutes	37–44	-1.5 to -2.5
Tri-Ramp Deplaning Optimistic (full fleet)	Time to Utilisation	~ 100–120 block-hours per day; full fleet x 6 turns x 4 minutes x 33%	146–176	-4.0 to -6.0
Neo Fleet Multiplier (A320neo vs CEO)	Engine technology	~ 15–20% fuel efficiency gain; multiplies all above levers; fleet phase-in dependent	Amplifies above gains	-55 to -80
SAF Mandate Headwind (1–5% blend, 2027–2030)	Regulatory cost (exogenous)	Uniform across carriers at industry level; heterogeneous at firm level (see Section 5.3)	+ 15 to + 106	+ 15 to + 106
<i>Notes: bps = basis points of CASK (INR per ASK). ATF = Aviation Turbine Fuel. Tri-ramp conservative scenario: 100 aircraft, 4 turns per day, 4 minutes saved per turn. Optimistic: full fleet deployment. Savings apply the Airbus weight-proportionality methodology (Airbus, 2019). SAF headwind: delta CASK = L/ASK x blend rate x SAF premium (INR per litre), where L/ASK is approximately 0.0425 for the A320-family fleet average. Sources: InterGlobe Aviation Ltd. (2024); Airbus (2019); MoCA (2025).</i>				

4.2 Entry Barriers to Cost Parity

We assess the barriers facing a potential entrant or existing rival seeking to replicate IndiGo's cost position using Bain's (1956) classification of absolute cost advantages, capital requirement barriers, and regulatory delay barriers. Table 3 presents the analysis. The key finding is that hardware parity costs INR 460–930 crore and approximately 24–36 months, placing it within reach of a well-capitalised carrier. System-level parity requires an additional execution gap of 3–5 years with very high failure risk, because the variance-suppression capability that integrates the individual levers into a cost-minimising system is path-dependent and cannot be purchased outright.

This analysis provides the empirical basis for treating IndiGo's cost asymmetry as conditionally durable rather than merely temporary. A rival that successfully replicates all hardware will still face a 3–5 year

organisational capability gap during which its CASK will exceed IndiGo's. The gap is persistent but not permanent; it is a dynamic cost asymmetry rather than a permanent monopoly barrier.

Table 3
Entry Barriers to Cost Parity: Classification and Assessment (Bain, 1956 Framework)

Barrier Component	Capital Cost (INR Crore)	Time to Operational Parity	Barrier Type (Bain, 1956)	Durable Barrier?
Ground operations process redesign (tri-ramp choreography, station KPIs)	50–150	12–18 months	Absolute cost advantage (knowledge-based)	No (replicable, but cultural embedding takes 2–3 years)
EFB hardware procurement + DGCA regulatory approval	80–200	18–24 months	Regulatory delay barrier	No (administrative; timeline is binding, not capital)
Slimline seat fleet replacement (full narrow-body fleet)	300–500	24–36 months	Capital requirement barrier	Partially (capital-constrained rivals excluded)
KPI digitisation infrastructure and closed-loop audit architecture	30–80	12–18 months	Absolute cost advantage (organisational capital)	No (tools purchasable; integration takes 2 + years)
Total direct replication cost	460–930	24–36 months (hardware parity)	Composite capital and knowledge barrier	Partial
System-level integration (organisational capability, culture, variance suppression)	Not quantifiable	3–5 years minimum	Absolute cost advantage (path-dependent; Bain Type I)	Yes (path dependence creates execution gap rivals cannot close with capital alone)
<i>Notes: Barrier Type classification follows Bain (1956): absolute cost advantage = lower unit costs at all output levels; capital requirement = capital access differentiates entrants from incumbents; regulatory delay = administrative timelines delay competitive entry. Capital estimates are illustrative ranges derived from programme costs at comparable carriers (CAPA, 2024; Jefferies India, 2024). The execution gap row reflects path dependence: rivals must build the organisational capability stock from zero under competitive pressure. EFB = Electronic Flight Bag; DGCA = Directorate General of Civil Aviation; KPI = Key Performance Indicator.</i>				

4.3 Second-Order Costs of Tight Coupling

Prior analyses of airline cost minimisation treat efficiency compounding as monotonic. Three second-order constraints are material to the welfare analysis that follows. Higher utilisation from tri-ramp and scheduling tightness accelerates aircraft depreciation cycles, bringing forward heavy maintenance intervals. We estimate this reduces the utilisation benefit of the conservative tri-ramp scenario by 15–

25%, a correction that does not alter the sign of the CASK advantage but reduces its magnitude. Scheduling tightness also creates crew fatigue and labour relations risk that is absent from the CASK waterfall: as the IndiGo workforce exceeds 35,000 (InterGlobe Aviation Ltd., 2024), the labour relations dimension of operational tightness is a structural risk to the cost position. Most importantly, tight coupling generates systemic brittleness: in network terms (Watts, 2002), reduced slack at each node lowers the cascade threshold, making the system more susceptible to global failure from local disruption. This is the fragility property formalised in Section 5.

5 Formal Model

5.1 Profit Function and Cost Decomposition

Consider firm i operating in the Indian domestic aviation market over period t . The firm's profit is:

Equation 1: $\pi_{i,t} = (P_{i,t} - \text{CASK}_{i,t}(s_{i,t})) \times \text{LF}_{i,t} \times \text{ASK}_{i,t} - p(s_{i,t}) \times L_{i,t}$

where $P_{i,t}$ is revenue per available seat kilometre (RASK); $\text{CASK}_{i,t}(s_{i,t})$ is cost per available seat kilometre, a decreasing and convex function of operational slack level $s_{i,t}$; $\text{LF}_{i,t}$ is the load factor; $\text{ASK}_{i,t}$ is available seat kilometres; $p(s_{i,t})$ is the probability of a major service disruption, a decreasing and convex function of $s_{i,t}$; and $L_{i,t}$ is the expected loss conditional on disruption, comprising revenue loss, direct compensation liability, and reputational damage. CASK decomposes as:

Equation 2: $\text{CASK}_{i,t}(s_{i,t}) = \text{CASK}_{\text{base},i,t} - [\sum_j \text{eps}_j(s_{i,t})] + \Delta_{\text{SAF},i,t}$

where $\text{CASK}_{\text{base},i,t}$ is the firm's baseline cost structure absent efficiency investment; $\text{eps}_j(s_{i,t})$ is the cost saving from mechanism j , a decreasing and concave function of slack (tighter operations generate larger savings but with diminishing marginal return and at the cost of reduced buffer); and $\Delta_{\text{SAF},i,t}$ is the exogenous SAF compliance cost increment common to all carriers at a given blend mandate. Key properties: partial derivative of $\text{CASK}_{i,t}$ with respect to $s_{i,t}$ is positive (more slack raises CASK); second derivative is positive (convex in slack). Similarly, $dp/ds_{i,t}$ is negative (more slack reduces disruption probability) and the second derivative is positive (convex).

5.2 Optimal Slack and Endogenous Disruption Risk

The firm chooses slack $s_{i,t}$ to minimise expected total cost:

Equation 3: $E[C_{i,t}(s)] = \text{CASK}_{i,t}(s) \times \text{ASK}_{i,t} + p(s) \times L_{i,t}$

The first-order condition for private optimal slack s^* is:

Equation 4: $(d \text{CASK}_{i,t} / d s_{i,t}) \times \text{ASK}_{i,t} = |dp / ds_{i,t}| \times L_{i,t}$

At the optimum, the marginal CASK cost of adding one unit of slack equals the marginal reduction in expected disruption loss. This is the efficiency-resilience trade-off stated precisely. The firm adds slack

until the operational cost of doing so exactly equals the expected disruption cost it averts.

The welfare-relevant insight concerns the social versus private divergence. When disruption costs are partially externalised, the firm uses L_i at its private value, which includes only compensated losses. The social planner would use L_i^{social} , which includes uncompensated passenger time costs, business disruption, and network spillovers. Since $L_i^{\text{social}} > L_i^{\text{private}}$ (established empirically in Section 7.1), the social optimum s^{**} satisfies:

Equation 5: $s^{**} > s^*$ iff $L_i^{\text{social}} > L_i^{\text{private}}$

Firms rationally underinvest in system redundancy because they do not bear the full social cost of disruption. The regulatory instruments in Section 7.2 are designed to close this gap.

5.3 Comparative Statics: The SAF Regulatory Shock

The SAF mandate introduces an exogenous cost increment Δ_{SAF} that is common across carriers at the industry level but generates heterogeneous firm-level profit impacts. From Equation 1:

Equation 6: $d\pi_i / d\Delta_{\text{SAF}} = -LF_i \times \text{ASK}_i < 0$

SAF reduces profit for all carriers. The proportional margin impact, however, is inversely proportional to the baseline margin:

Equation 7: $|d\pi_i / d\Delta_{\text{SAF}}| / \pi_i = 1 / (P_i - \text{CASK}_i) = 1 / \text{margin}_i$

A carrier with baseline margin of +INR 0.52 per ASK (IndiGo, FY2024) faces a proportional margin compression of $1/0.52 = 1.92$ per unit of SAF shock. A carrier with a negative baseline margin faces unbounded proportional compression from an identical absolute cost increment. This is the formal statement of the competitive filter argument: a uniform environmental mandate generates heterogeneous market structure effects that are proportional to the inverse of the pre-existing margin distribution across firms.

A second comparative statics result concerns the interaction between SAF compliance and fragility. Equation 1 shows that higher Δ_{SAF} reduces profit at any slack level s_i . This creates an incentive to reduce s_i to recover the lost margin, which from Equation 4 implies that $p(s_i)$ increases as a second-order consequence of the SAF mandate. Environmental regulation therefore indirectly amplifies systemic fragility risk: firms under margin pressure from the SAF mandate have a stronger incentive to reduce operational slack, raising the cascade probability.

6 Empirical Illustration

6.1 CASK Decomposition with Ranges

Table 2, presented in Section 4.1, shows the CASK contribution of each efficiency lever as a range reflecting ATF price sensitivity and adoption-rate uncertainty. The total efficiency gain from all four levers under conservative assumptions is approximately 59–87 basis points of CASK annually, before the SAF headwind. Under the 5% blend scenario (2030), the SAF headwind of 75–106 basis points exceeds the efficiency gain at the conservative end, implying that continued efficiency improvement is a necessary condition for positive margins through 2030. Under the optimistic efficiency scenario, the headwind is partially absorbed. This range-based analysis replaces the point estimates of prior versions, which overstated precision by assuming constant ATF prices and uniform adoption rates.

6.2 The December 2025 Operational Crisis

In December 2025, IndiGo cancelled over 4,500 flights, disrupted approximately one million passengers, and incurred direct compensation liabilities of INR 24 crore (Times of India/NDTV, 2025). We treat this event as empirical evidence for the cascade mechanism predicted by the formal model and by Watts (2002) network cascade theory.

IndiGo's scheduling system operates approximately 1,800 flight slots per day across 300+ aircraft, each running 5–7 rotations. Modelling this as a directed network, each flight node is connected to subsequent rotation nodes at the same aircraft and crew base. In Watts's (2002) threshold cascade framework, a cascade occurs when a local shock exceeds the absorption capacity of connected nodes. With scheduling slack at or near zero, the threshold capacity of each node is effectively zero: any delay at one node that cannot be absorbed by a local buffer propagates to the connected downstream rotation. If a shock affects n initial nodes and generates k downstream failures per propagation step, the cascade magnitude after m steps is approximately $n \times k^m$. For $n = 50$ initial disruptions and $k = 3$, two propagation steps yield 450 cascaded disruptions, consistent with the scale of the December 2025 event over a multi-day window. The cascade simulation workbook, including the full derivation of $k(s)$ and all propagation calculations across five slack scenarios, is given in Online Resource 5.

Table 4 maps each cost minimisation dimension to its cascade mechanism and December 2025 empirical relevance. The efficiency-resilience trade-off is not a theoretical abstraction: it is a structural property of the operational architecture, and the December 2025 event provides direct empirical evidence that the private optimal slack level s^* was set below the level required to contain a moderately large exogenous shock.

Table 4
Efficiency-Resilience Dimensions and Cascade Mechanisms (December 2025)

Dimension	Cost Benefit	Resilience Cost (Slack Reduction)	Cascade Mechanism (Watts, 2002)	December 2025 Empirical Relevance
Minutes (Ground ops)	Aircraft utilisation up; block-hours recovered	Schedule buffer reduced; recovery windows compressed	Delay at node A propagates along scheduling edges to all downstream rotations	Tight scheduling converted initial shock into a multi-airport cancellation cascade; no buffer absorbed the initial failure
Kilos (Weight discipline)	Fuel burn reduced; trip cost down	Payload and reserve margins optimised; operational discretion compressed	Weight-critical dispatch decisions under pressure increase variance in go/no-go outcomes	Crew and aircraft resource pressure reduced capacity for ad-hoc decision making during the disruption
Clicks (Digitisation)	Variance suppressed; KPIs enforced system-wide	System rigidity increases; local adaptation reduced	Automated systems propagate errors through digital interdependencies faster than human recovery protocols	1,800 + daily scheduling slots linked digitally; limited manual workaround capacity when automated system entered disruption state
Neo Fleet Homogeneity	Fuel savings amplified; maintenance standardised	Fleet type concentration; type-specific shock exposure	AOG event pattern affects all aircraft in network simultaneously; no type-diverse fallback path	Single fleet type prevented disruption coverage through redeployment; homogeneity that reduces cost also concentrates failure risk
<i>Notes: Cascade Mechanism column applies the Watts (2002) threshold cascade framework to each dimension. December 2025 Relevance column applies that mechanism to the known facts of the disruption (Times of India/NDTV, 2025). The formal model linking operational slack to disruption probability is in Equations 3–5. Root-cause analysis for the December 2025 event has not been publicly disclosed by IndiGo; the cascade mechanism is inferred from available data.</i>				

6.3 Competitive Structure

Table 8 presents the competitive benchmarking analysis. The INR 2.2–2.7 CASK gap between IndiGo and the Air India Group (post-Vistara merger) is the central structural fact of the competitive landscape. The HHI of approximately 4,600 places the market firmly in the highly concentrated range. In the Indian context, the welfare implications of this concentration differ from standard oligopoly analysis because IndiGo's dominant position is cost-driven rather than capacity-driven: the firm achieves its market share

by offering structurally lower fares enabled by its cost position rather than by restricting capacity to raise prices. Whether this distinction is welfare-relevant depends on whether concentration drives IndiGo's slack decision below the social optimum through a different channel: the absence of competitive pressure to invest in resilience. We return to this in Section 7.

Table 8
Competitive Benchmarking: Indian Domestic Aviation Market (FY2024-2025)

Metric	IndiGo	Air India Group (post-Vistara)	SpiceJet	Notes
Domestic Market Share (%)	~ 65%	~ 24%	~ 5%	DGCA Jun-Aug 2025 (DGCA, 2025)
CASK (INR per ASK, FY2024)	4.96	~ 7.2 (estimate)	~ 6.5 (estimate)	IndiGo AR (InterGlobe Aviation Ltd., 2024); others from analyst consensus (CAPA, 2024)
RASK-CASK Spread (INR per ASK)	+ 0.52	~1.5 (estimate)	~1.0 (estimate)	Negative spread = structural loss at operational level
Herfindahl-Hirschman Index (market share basis)	~ 4,600 (combined)	n/a	n/a	HHI > 2,500 = highly concentrated per DOJ thresholds
CO ₂ e per ASK (g)	61.7	~ 80–90 (estimate)	~ 75 (estimate)	IndiGo BRSR (InterGlobe Aviation Ltd., 2025); estimates for others
Notes: Market share from DGCA (2025). IndiGo CASK and RASK from InterGlobe Aviation Ltd. (2024). Air India Group and SpiceJet CASK figures are analyst consensus estimates from CAPA (2024) and should be treated as directional. HHI calculated from reported market shares; Herfindahl-Hirschman Index threshold of 2,500 for highly concentrated markets follows Department of Justice (2023) Merger Guidelines. CO ₂ e/ASK for non-IndiGo carriers is estimated.				

7 Welfare Analysis and Regulatory Design

7.1 Welfare Decomposition of Cost Minimisation

Table 5 decomposes the welfare effects of IndiGo's cost minimisation strategy using December 2025 as the empirical anchor. The central finding is that the INR 24 crore compensation paid by IndiGo represents an estimated 18–41% of the social disruption cost, placing the externality gap at INR 35–110 crore for a single event.

Passenger time cost is estimated as follows: approximately one million passengers were affected, of whom an estimated 50% experienced serious disruption (cancellation or delay exceeding 3 hours). Average disruption time is taken as 3 hours. Indian urban wage data from NSSO (2019) implies an

opportunity cost of INR 100–300 per hour across the relevant income distribution, yielding a time cost of INR 15–45 crore. Adding rebooking and logistics costs raises the total uncompensated externality to INR 35–110 crore as shown in Table 5. Against this, IndiGo's annual consumer surplus transfer from below-market fares is estimated at INR 2,000 crore per year if 30% of CASK savings are passed through to fares across the fleet, providing a welfare justification for cost competition that is quantitatively much larger than the disruption externality risk.

Table 5

Welfare Decomposition of Disruption Externality: Private vs. Social Cost Accounting (December 2025 Event)

Welfare Component	Private Accounting (IndiGo)	Social Accounting (Full Cost)	Externality Gap (Uncompensated)	Regulatory Implication
Consumer surplus from low-fare access	Captured in RASK-CASK spread (+ INR 0.52)	Full consumer surplus transfer to passengers	Zero (fully internalised via fare prices)	No regulatory intervention required; cost competition benefits consumers
Direct disruption compensation (December 2025)	INR 24 crore paid (DGCA mandate)	INR 24 crore	Zero (DGCA rules cover direct financial loss)	Existing compensation rules function correctly for direct financial loss
Passenger time cost (1 million passengers; ~3 hours average @ INR 100–300 per hour) ^a	Not compensated; absent from private cost function	INR 30–90 crore (illustrative)	INR 30–90 crore (not internalised)	Current DGCA rules do not cover time cost; regulatory gap
Rebooking, logistics, business disruption cost	Not compensated	INR 5–20 crore (illustrative)	INR 5–20 crore	Partial coverage under air passenger rights; gap remains
Total disruption externality (December 2025 event)	INR 24 crore (private)	INR 59–134 crore (social)	INR 35–110 crore (18–41% internalised)	Current compensation covers approximately 18–41% of estimated social disruption cost
Implication for optimal slack s^*	s^* set where $dCASK/ds \times ASK = dp/ds \times 24$ crore	s^{**} set where $dCASK/ds \times ASK = dp/ds \times 59-134$ crore	$s^{**} > s^*$ (private underinvestment in redundancy)	Mandatory slack or enhanced liability rules required to close the gap

Notes. ^a Passenger time cost calculated as: 0.5 million seriously disrupted passengers x 3 hours x INR 100–300 per hour = INR 15–45 crore; adjusted to INR 30–90 crore to include rebooking, logistics, and business disruption components. INR 100–300 per hour range reflects the urban wage distribution from NSSO (2019) 75th Round. These are illustrative estimates; a primary passenger survey would substantially improve precision. DGCA compensation mandate per Ministry of Civil Aviation guidelines (MoCA, 2025). The social accounting column reflects the social planner's welfare function inclusive of all uncompensated externalities.

7.2 Regulatory Instrument Comparison

Following Shavell (1984), we compare two instruments for internalising the disruption externality. We then derive Proposition 1.

Liability regime. The regulator requires the firm to compensate passengers for the full social cost of disruptions, including uncompensated time and business costs. If L_i is set at the social value L_i^{social} , the firm's optimal slack from Eq. 4 becomes: $(d \text{CASK}_i / d s_i) \times \text{ASK}_i = |dp/d s_i| \times L_i^{\text{social}}$, which achieves $s^* = s^{**}$. The regulatory challenge is eliciting the true L_i^{social} from a firm with private information about its cascade propagation properties and the consequential losses its disruptions impose.

Mandatory slack regime. The regulator mandates a minimum scheduling buffer $s_{\min}$ at airports operating above a specified slot utilisation threshold. This directly constrains the firm's slack decision without requiring observation of L_i . The regulator must observe s_i (directly measurable from published flight schedules) rather than L_i (not directly observable).

Proposition 1

Under asymmetric information about the firm's disruption probability $p(s)$, mandatory minimum slack requirements weakly dominate enhanced compensation liability as a welfare instrument when the regulator's cost of observing s_i is lower than the cost of eliciting the firm's true L_i .

Proof

Under liability, welfare optimality requires the firm to truthfully reveal L_i^{social} . The firm has a strategic incentive to understate L_i if the regulator cannot independently verify non-contractible components of the social disruption cost, notably passenger time costs and consequential business losses, which are not recorded in any transaction between IndiGo and affected passengers. Truthful revelation of L_i^{social} therefore requires costly verification by the regulator. Under mandatory slack, the regulator observes s_i directly from DGCA-mandated schedule disclosures. Since schedule data are publicly observable at near-zero cost, while passenger time cost verification requires a primary survey, the information advantage of mandatory slack dominates liability under standard asymmetric information conditions. Mandatory slack weakly dominates in welfare terms subject to the enforcement cost of observing s_i being lower than the information elicitation cost of L_i , a condition satisfied in the Indian aviation regulatory context. Square.

The practical implication is a DGCA rule requiring minimum scheduling buffers of 5–8% at airports operating above 85% slot utilisation. This does not require IndiGo to reveal any private information. It requires DGCA to verify departure schedules, which it already publishes.

7.3 SAF as Multi-Objective Regulation

The SAF mandate is designed to correct a carbon emissions externality. Equations 6–7 show that it simultaneously generates a market structure externality. We formalise this in Proposition 2, following

Fischer and Newell (2008).

Proposition 2

A carbon cost mandate that imposes a uniform cost increase on an industry with pre-existing cost asymmetries generates an unintended market structure externality whose welfare sign depends on whether the increase in market concentration from high-cost carrier exit exceeds the environmental welfare gain from reduced emissions.

Proof

Social welfare $W = W_e(\text{emissions}) + W_m(\text{concentration, fares})$, where W_e is increasing as emissions fall and W_m is decreasing as concentration increases (standard Cournot oligopoly result). A SAF mandate at blend rate b generates: (i) $dW_e/db > 0$ by construction (mandate reduces aviation emissions); (ii) $dW_m/db = (dW_m/dHHI)(dHHI/db)$, where $dHHI/db > 0$ if the mandate exits high-cost carriers (raising IndiGo's share), and $dW_m/dHHI < 0$. The net welfare effect $dW/db = dW_e/db + dW_m/db$ is ambiguous in general. In the Indian case, the market was already highly concentrated (HHI approximately 4,600) before any SAF-induced exit. Standard industrial organisation analysis (Tirole, 1988) implies that the marginal welfare loss from additional concentration is decreasing in the existing concentration level, making $|dW_m/dHHI|$ small at the current HHI. The net welfare effect is likely positive, but the magnitude is an empirical question that cannot be resolved from available data. The key regulatory implication is that the SAF mandate's design should account for its market structure effects, for example by conditioning the mandate on market concentration levels or including a merger review trigger for any carrier exit attributable to SAF compliance costs. Square.

Table 7 presents the empirical illustration. At 5% blend in 2030, carriers with CASK above INR 7.0 face structural insolvency risk from an absolute cost increment that IndiGo absorbs without threatening profitability. The SAF mandate may thus function as an inadvertent competitive filter, a welfare outcome not part of its design objective.

Table 7
SAF Cost Sensitivity with Heterogeneous Firm-Level Margin Impact

Scenario (Blend / Year)	Delta CASK (INR / ASK)	IndiGo Margin (Baseline + 0.52)	Proportional Margin Compression: 1/margin	High-CASK Carrier (Baseline – 1.0 est.)	Competitive Filter Effect
1% / 2027	+ 0.013– 0.015	+ 0.505 to + 0.507	2.9%	Deepens loss; no margin to absorb	Minimal: uniform cost increase; IndiGo retains structural lead
2% / 2028	+ 0.030	+ 0.490	5.8%	Significant additional loss; cash burn acceleration	Moderate: less- efficient carriers face liquidity pressure
5% / 2030	+ 0.075– 0.106	+ 0.414 to + 0.445	15–20%	Structural insolvency risk at CASK > 7.0	Strong: SAF mandate accelerates exit of high-CASK carriers; unintended market structure externality
<i>Notes: Margin compression formula: $d\pi_i / d\Delta_{SAF} / \pi_i = 1 / \text{margin}_i$ (Eq. 7). IndiGo baseline margin = + INR 0.52 per ASK (FY2024). High-CASK carrier margin estimate = -INR 1.0 per ASK (CAPA, 2024; directional). Delta CASK formula: $L/\text{ASK} \times \text{blend rate} \times \text{SAF premium per litre}$, where L/ASK is approximately 0.0425 and SAF premium is INR 30–50 per litre above ATF. Sources: MoCA (2025); IATA (2024); ICAO (2023).</i>					

7.4 Sensitivity Analysis: Disruption Frequency

The welfare case for mandatory slack depends critically on the frequency of major disruption events. A once-in-five-years event produces a lower expected annual externality than a once-in-two-years event. Table 6 presents a two-dimensional sensitivity analysis crossing disruption frequency against the passenger time cost assumption. The mandatory slack cost of INR 15–30 crore per year is based on a CASK increase of 10–20 basis points applied to IndiGo's FY2024 ASK base.

Table 6
Disruption Frequency Sensitivity: Expected Annual Externality vs. Mandatory Slack Cost

Scenario	Disruption Frequency (Major Events / Year)	Time Cost Assumption (INR / Passenger Hour)	Expected Annual Externality (INR Crore)	Mandatory Slack Cost Self-Financing?
Conservative	0.2 (once in 5 years)	INR 100	7–18	Borderline: slack cost (INR 15–30 crore) may exceed expected externality under lowest assumptions
Base Case	0.5 (once in 2 years)	INR 200	30–55	Yes: mandatory slack cost (INR 15–30 crore) is below expected externality under base assumptions
Moderate	1.0 (annually)	INR 200	59–110	Yes: clear net welfare gain from regulatory intervention
High Frequency	2.0 (twice annually)	INR 300	118–268	Yes: strongly justified; mandatory slack is substantially underpriced relative to social benefit
<i>Notes: Expected Annual Externality = Single-event externality x disruption frequency. Single-event externality range: INR 35–110 crore (Table 5 base case). Mandatory slack cost: 10–20 basis points CASK increase applied to FY2024 ASK base, yielding approximately INR 15–30 crore per year. A regulatory correction is welfare-positive when Expected Annual Externality > Mandatory Slack Cost. Self-financing threshold fails only under the conservative scenario (once in five years, INR 100 per hour time cost), and even there the externality gap is INR 7–18 crore against a slack cost of INR 15–30 crore. Passenger time cost range anchored to NSSO (2019) urban wage data.</i>				

The sensitivity analysis confirms that mandatory slack is welfare-positive under three of the four scenario combinations and borderline under the conservative case. The robust conclusion is that the regulatory correction is warranted under any disruption frequency assumption consistent with the December 2025 event representing a non-trivial probability event rather than a once-in-a-generation outlier. The full welfare parameter grid with adjustable assumptions is given in Online Resource 6.

8 Limitations

Five limitations merit explicit acknowledgment. First, the formal model is a reduced-form theoretical framework rather than a structurally estimated model. The disruption probability function $p(s)$ and loss function L are characterised qualitatively rather than estimated econometrically; full structural estimation would require disruption frequency data and passenger-level welfare surveys not currently available in the public domain.

Second, the welfare decomposition in Table 5 relies on illustrative passenger time cost estimates derived from aggregate wage data (NSSO, 2019). A primary passenger welfare survey would substantially improve precision, particularly for the consequential business disruption component.

Third, the December 2025 disruption root-cause analysis remains incomplete in the public record. The cascade mechanism proposed in Section 6.2 is consistent with available data and with Watts's (2002) network cascade framework, but is not confirmed by an IndiGo internal investigation that, to our knowledge, has not been publicly released.

Fourth, competitor CASK data for Air India Group and SpiceJet are analyst consensus estimates rather than audited figures. The competitive benchmarking in Table 8 and the SAF heterogeneous impact analysis in Table 7 should be treated as directional.

Fifth, the paper does not include an econometric identification strategy for the causal claim that cost asymmetry drives market share persistence. A panel regression of CASK on market share with carrier fixed effects and year fixed effects, using COVID as a shock or route-level entry events as instruments, would strengthen the causal interpretation. This extension is left for future research.

9 Conclusion

We set out to examine three questions. The answers follow from the analysis.

Does firm-level cost asymmetry translate into durable market share under exogenous regulatory cost shocks? Conditionally yes. IndiGo's CASK of INR 4.96 per ASK versus rivals at INR 6.5–7.2 produces a margin advantage that survives the SAF shock at the 1–2% blend level (2027–2028). At 5% blend (2030), the margin compresses by 15–20% but remains positive; rivals at negative baseline margins face structural insolvency. The SAF mandate functions as an unintended competitive filter: the carbon externality correction produces a market structure externality by accelerating the exit of high-cost carriers.

Do private incentives to minimise operational costs generate negative externalities through underinvestment in redundancy? Yes. We demonstrate formally (Equations 3–5) that private optimal slack s^* falls below socially optimal slack s^{**} when disruption costs are partially externalised. The December 2025 event provides empirical evidence: direct compensation of INR 24 crore covered an estimated 18–41% of the true social disruption cost. The externality gap is INR 35–110 crore from a single major disruption, and the mandatory slack correction costs INR 15–30 crore per year. The regulatory intervention is welfare-positive under all but the most conservative disruption frequency assumptions.

What regulatory instrument best internalises the externality? Proposition 1 establishes that mandatory minimum scheduling buffers weakly dominate enhanced compensation liability under asymmetric information about the firm's disruption probability, because schedule data are publicly observable while

passenger time costs are not contractible. Proposition 2 establishes that the SAF mandate generates an unintended market structure externality whose net welfare sign is ambiguous but whose existence calls for a supplementary regulatory response, for example a merger review trigger conditioned on SAF-attributable carrier exit.

The results suggest that cost minimisation is not unambiguously welfare-enhancing at the firm level, because the same properties that minimise expected cost in normal operations maximise cascade damage when shocks occur, and a fraction of that damage is borne by consumers rather than the firm. Optimal regulatory design must therefore address both the disruption externality and the unintended market structure effects of environmental mandates simultaneously. The challenge is calibration: the consumer surplus from cost competition is an estimated INR 2,000 crore per year at IndiGo's scale. The annual disruption externality is INR 7-110 crore depending on disruption frequency assumptions. Regulators should internalise the externality without eliminating the competition that generates the surplus. Mandatory scheduling buffers at congested airports are the most tractable instrument for doing so. Replication data and Stata/R code are given in Online Resource 3. CASK decomposition calculations with adjustable ATF price assumptions are given in Online Resource 4.

Declarations

Competing Interests.

The author has no relevant financial or non-financial interests to disclose.

Funding.

The author received no financial or non-financial support for the conduct of this research or the preparation of this manuscript. No funding was received to assist with the preparation of this submission.

Author Contribution

T.G. conceived the study, developed the formal model, conducted all empirical analysis, constructed the supplementary datasets and replication workbooks, and wrote the manuscript in its entirety. T.G. reviewed and approved the final submitted version.

Data Availability

The carrier-year panel dataset, regression replication dataset, CASK decomposition workbook, network cascade simulation workbook, and welfare parameter grid underlying all empirical results in this study are provided as Online Resources 2–6 in the Supplementary Information. All data are derived from

publicly available sources: IndiGo Annual Reports FY2019–FY2024 (InterGlobe Aviation Ltd., available at <https://www.goindigo.in/investor-relations.html>); DGCA Monthly Domestic Air Traffic Statistics (Directorate General of Civil Aviation, Government of India, available at <https://dgca.gov.in>); SpiceJet Limited Annual Reports (Bombay Stock Exchange, available at <https://www.bseindia.com>); Air India audit reports (Comptroller and Auditor General of India, available at <https://cag.gov.in>); and Go First NCLT insolvency filing disclosures. Non-IndiGo CASK figures are analyst consensus estimates from CAPA India (2024) and Jefferies India (2024) and are clearly labelled as such with explicit confidence ranges and data quality grades in Online Resource 2. No proprietary datasets, survey data, or restricted-access data were used. All replication code (Stata and R) is provided in Online Resource 3. The supplementary data and code are sufficient to independently verify and reproduce all regression results, cascade simulations, and welfare calculations reported in the paper.

References

1. Airbus. (2019). *Getting to grips with fuel economy (A320 family)*. Airbus Customer Services.
2. Allen, F., & Gale, D. (2000). Financial contagion. *Journal of Political Economy*, 108(1), 1-33. <https://doi.org/10.1086/262109>
3. Bain, J. S. (1956). *Barriers to new competition: Their character and consequences in manufacturing industries*. Harvard University Press.
4. Baumol, W. J., Panzar, J. C., & Willig, R. D. (1982). *Contestable markets and the theory of industry structure*. Harcourt Brace Jovanovich.
5. Borenstein, S. (1989). Hubs and high fares: Dominance and market power in the U.S. airline industry. *RAND Journal of Economics*, 20(3), 344-365. <https://doi.org/10.2307/2555590>
6. CAPA Centre for Aviation. (2024). *India aviation market annual review and outlook 2024-2025*. CAPA India.
7. Directorate General of Civil Aviation (DGCA). (2025). *Monthly domestic air traffic statistics (June-August 2025)*. Government of India. <https://dgca.gov.in>
8. Fischer, C., & Newell, R. G. (2008). Environmental and technology policies for climate mitigation. *Journal of Environmental Economics and Management*, 55(2), 142-162. <https://doi.org/10.1016/j.jeem.2007.11.001>
9. International Air Transport Association (IATA). (2024). *IATA sustainable aviation fuel outlook 2024*. IATA.
10. International Civil Aviation Organization (ICAO). (2023). *CORSIA: Carbon offsetting and reduction scheme for international aviation*. ICAO. <https://www.icao.int/environmental-protection/CORSIA>
11. InterGlobe Aviation Ltd. (2024). *Annual report FY2019-FY2024 series*. <https://www.goindigo.in/information/investor-relations.html>
12. InterGlobe Aviation Ltd. (2025). *Business responsibility and sustainability report FY2024-25*. IndiGo Investor Relations.

13. Jefferies India. (2024). *India aviation sector note: CASK and competitive dynamics*. Jefferies.
14. Laffont, J.-J., & Tirole, J. (1993). *A theory of incentives in procurement and regulation*. MIT Press.
15. Ministry of Civil Aviation (MoCA). (2025). *SAF blending mandate notification*. Press Information Bureau, Government of India.
16. Morrison, S. A., & Winston, C. (1987). Empirical implications and tests of the contestability hypothesis. *Journal of Law and Economics*, 30(1), 53-66. <https://doi.org/10.1086/467130>
17. Morrison, S. A., & Winston, C. (1995). *The evolution of the airline industry*. Brookings Institution Press.
18. National Sample Survey Office (NSSO). (2019). *Key indicators of social consumption in India: Health, NSS 75th Round (July 2017-June 2018)*. Ministry of Statistics and Programme Implementation, Government of India.
19. Perrow, C. (1984). *Normal accidents: Living with high-risk technologies*. Basic Books.
20. Requate, T. (2005). Dynamic incentives by environmental policy instruments: A survey. *Ecological Economics*, 54(2-3), 175-195. <https://doi.org/10.1016/j.ecolecon.2004.12.030>
21. Reuters. (2022). IndiGo deploys three-ramp boarding at major Indian airports. Thomson Reuters.
22. Shavell, S. (1984). A model of the optimal use of liability and safety regulation. *RAND Journal of Economics*, 15(2), 271-280. <https://doi.org/10.2307/2555528>
23. Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509-533. [https://doi.org/10.1002/\(SICI\)1097-0266\(199708\)18:7<509::AID-SMJ882>3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z)
24. Times of India/NDTV. (2025, December). IndiGo operational disruption: 4,500 cancellations, approximately one million passengers affected [Multiple published reports]. <https://timesofindia.com>; <https://www.ndtv.com>
25. Tirole, J. (1988). *The theory of industrial organization*. MIT Press.
26. Watts, D. J. (2002). A simple model of global cascades on random networks. *Proceedings of the National Academy of Sciences*, 99(9), 5766-5771. <https://doi.org/10.1073/pnas.082090499>

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SIPackageJREFinal.zip](#)