

Market Structure Distortion and Load Imbalance as Determinants of Trucking Cost Efficiency: Empirical Evidence from Indonesia's Logistics Industry

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Abstract

The high proportion of logistics costs in Indonesia, accounting for 23.5% of the Gross Domestic Product (GDP), underscores the urgency of improving efficiency in land transportation systems, particularly the trucking sector. This study aims to identify and measure the simultaneous effects of two main determinants—load imbalance (empty backhaul) and market structure distortion—on the formation of trucking transportation costs. The structural and measurement models were analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with the support of SmartPLS software, based on primary data collected from more than 100 respondents in the logistics industry. The findings reveal that market structure distortion exerts a dominant influence ($\beta = 1.278$), followed by empty backhaul ($\beta = 0.176$), with a high predictive capability ($R^2 = 0.724$; Adjusted $R^2 = 0.719$). All constructs demonstrate satisfactory convergent validity and high reliability (AVE > 0.626; CR > 0.893). These results reinforce the urgency of freight market reform and the digitalization of load consolidation systems as integrated strategies to reduce national logistics costs.

1. Introduction

The logistics sector plays a critical role in driving industrial productivity and trade competitiveness. In Indonesia, however, logistics costs remain disproportionately high, undermining national supply chain efficiency and reducing export competitiveness. The **National Logistics System (Sislognas)** launched by the government in 2012 has aimed to improve integration among modes, yet cost efficiency has not improved substantially (World Bank, 2021).

According to the **ASEAN Logistics Report (2022)**, Indonesia's logistics cost structure is dominated by **trucking**, accounting for approximately **70–80% of inland freight movements**. However, the sector's operational model is often inefficient due to *empty backhaul trips*, fragmented market structure, and lack of transparency in freight rate formation. The imbalance between outbound and return cargo creates asymmetric cost burdens for operators and inflates overall logistics expenditures.

Load imbalance occurs when trucks return empty from destinations due to spatially uneven economic activities and limited access to return cargo. This inefficiency significantly raises cost per trip and fuel consumption, reducing both profitability and asset productivity (Rodrigue, 2020). Meanwhile, **market structure distortion** emerges from over-fragmentation, excessive brokerage dependence, and the dominance of informal logistics networks. Such conditions foster unequal bargaining power among market participants, where small operators are unable to compete fairly with dominant brokers.

Several reports—including **Purnomo (2023)**—indicate that structural inefficiency in Indonesia’s trucking market stems from the absence of digital platforms that could match cargo and capacity effectively. Instead, traditional intermediaries dominate cargo allocation, resulting in opaque pricing and inflated freight margins. This dynamic perpetuates high logistics costs and limits competitiveness across the transport chain.

Given this context, this study seeks to empirically quantify the simultaneous impact of **load imbalance** and **market structure distortion** on trucking cost efficiency using the **SEM-PLS** method. Beyond confirming existing theoretical assumptions, this paper contributes by integrating *industrial organization theory* with *operational imbalance dynamics* in a developing economy framework.

1.1 Literature Review

1.1.1 Load Imbalance and Empty Backhaul

Load imbalance represents a fundamental inefficiency in freight logistics, particularly for truck-based operations. It refers to the unequal distribution of cargo demand between origin and destination routes, often leading to **empty backhaul trips**—where trucks return without load. As a result, carriers must recover costs from one-way trips, increasing per-unit freight prices (Zhang & Jiang, 2019).

Rodrigue (2020) emphasized that load imbalance contributes to 15–30% of total inefficiencies in developing economies’ trucking operations. In Indonesia, the imbalance is further aggravated by geographic dispersion of economic centers, where manufacturing and consumption activities are concentrated in Java, while outer islands serve mainly as raw material sources.

According to **Purnomo (2023)**, more than 60% of inter-provincial trucking routes in Indonesia are *unidirectional*, creating systemic inefficiencies. Carriers frequently factor the cost of empty returns into forward freight rates, thereby raising logistics costs for shippers. This structural imbalance, when combined with regulatory fragmentation and lack of digital coordination, sustains an inefficient freight ecosystem.

1.1.2 Market Structure Distortion

The **trucking industry’s structure** in Indonesia is characterized by extreme fragmentation: more than 80% of firms own fewer than 10 trucks, which prevents economies of scale (ASEAN Secretariat, 2022). This structural composition creates market vulnerability where brokers, or intermediaries, often control the flow of goods and price negotiations. As **Tirole (1988)** explains, imperfect competition within fragmented markets results in *allocative inefficiency*, where resources are mispriced due to asymmetrical information.

Empirical observations in Southeast Asia (World Bank, 2021; Purnomo, 2023) reveal that excessive brokerage layers inflate freight rates by 10–15%. Moreover, the lack of standardized cost databases and weak enforcement of fair competition laws allow informal logistics networks to thrive. In such markets, operational efficiency improvements often fail to translate into reduced costs because price-setting is controlled by intermediaries rather than operators.

1.1.3 Theoretical Framework

The **Industrial Organization (IO) theory** provides the conceptual foundation for analyzing cost formation in logistics markets. IO theory posits that market concentration, entry barriers, and asymmetric power structures determine pricing behavior and operational outcomes (Tirole, 1988).

In this study, two explanatory variables—**Load Imbalance (X_1)** and **Market Structure Distortion (X_2)**—are hypothesized to positively influence **Trucking Cost Inefficiency (Y)**. The underlying assumption is that both operational and structural inefficiencies increase total cost per transport unit. The theoretical relationships are illustrated below.

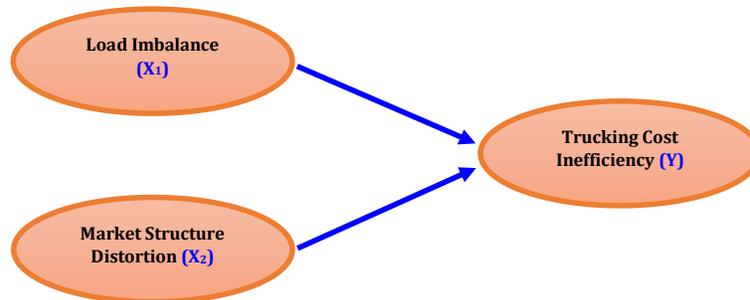


Figure 1: Conceptual Framework

Based on the reviewed literature, the following hypotheses are proposed:

- **H1:** Load imbalance has a positive (+) and significant effect on trucking cost inefficiency.
- **H2:** Market structure distortion has a positive (+) and significant effect on trucking cost inefficiency.

2. Research Methods

This research adopts a **quantitative-explanatory design**, developed to test causal relationships among structural and operational determinants of trucking cost inefficiency. The study integrates the conceptual lenses of *Industrial Organization (IO) theory* and *logistics cost analysis* to examine how **market structure distortion** and **load imbalance** jointly influence cost outcomes.

2.1 Research Design and Framework

The methodological framework follows a **variance-based structural equation modeling approach (PLS-SEM)**, chosen for its flexibility in handling complex, multivariate relationships with relatively limited sample sizes (Hair et al., 2021). The analysis consists of two interdependent components:

1. **The measurement model;** which assesses construct validity and reliability.
2. **The structural model;** which estimates causal pathways among latent variables.

The theoretical framework posits that market structure distortion (X_2) and load imbalance (X_1) both exert a positive influence on trucking cost inefficiency (Y). This model enables simultaneous testing of multiple hypotheses while accounting for multicollinearity and indirect effects.

2.2 Data Collection and Sampling Procedures

The empirical data were collected from **logistics companies and trucking operators** across five major industrial regions of Indonesia—Jakarta, Surabaya, Medan, Semarang, and Makassar. These regions represent the country's core freight corridors, capturing diverse operational realities.

Respondents were selected using a **purposive sampling technique**, emphasizing managerial and operational personnel directly involved in cost management and transport planning. Out of 150 distributed questionnaires, **103 valid responses** were returned and included in the analysis, yielding a response rate of 68.7%.

To ensure representativeness, the sample encompasses both **small and medium enterprises (SMEs)** and **large logistics service providers (LSPs)**. SMEs account for 58% of the sample, reflecting the industry's

fragmentation, while LSPs make up 42%, typically engaged in contract logistics and national distribution networks.

2.3 Measurement of Variables

Each latent variable was operationalized using multiple indicators adapted from established studies and contextualized for Indonesia's trucking market (Zhang & Jiang, 2019; Purnomo, 2023). "Responses were measured on a **five-point Likert scale**" (1 = *strongly disagree*; 5 = *strongly agree*).

- **Load Imbalance (X_1):** Measured by the ratio of empty return trips, variation in route demand, and utilization rate of outbound vs. inbound cargo.
- **Market Structure Distortion (X_2):** Measured by indicators of competition fairness, transparency of freight rate setting, and dependence on intermediaries.
- **Trucking Cost Inefficiency (Y):** Derived from the composite cost structure of operations, including cost per ton-kilometer, fuel expenditure, toll payments, and idle time.

To ensure contextual fit, the questionnaire items were reviewed by three logistics experts and two academic researchers before deployment. This **content validation step** confirmed the clarity and relevance of each indicator.

2.4 Data Processing and Analytical Techniques

The data were analyzed using **SmartPLS 4.0**, following a two-stage estimation process:

1. **Outer Model Evaluation (Measurement Model):** The reliability of each indicator was examined through *outer loadings*, *Composite Reliability (CR)*, and *Average Variance Extracted (AVE)*. Threshold values were set at >0.70 for loadings, >0.60 for AVE, and >0.70 for CR (Hair et al., 2021).
2. **Inner Model Evaluation (Structural Model):** The relationships between constructs were tested through *path coefficients (β)*, *t-statistics*, and *R² values*. Bootstrapping with 5,000 resamples was performed to assess the significance levels of each path.

The PLS-SEM approach was selected over covariance-based SEM because the model focuses on **prediction and exploration** rather than strict theory confirmation, which aligns with the study's objective to uncover practical determinants of cost inefficiency.

2.5 Validity and Reliability Testing

Preliminary testing demonstrated high construct reliability and validity across all variables.

- All outer loadings exceeded 0.708, confirming indicator reliability.
- **Composite Reliability (CR)** ranged from 0.893 to 0.924, surpassing the minimum acceptable threshold.
- **Average Variance Extracted (AVE)** values exceeded 0.626, confirming convergent validity.
- Discriminant validity was verified using the **Fornell-Larcker criterion**, ensuring that each construct shares more variance with its own indicators than with other constructs.

Furthermore, **Variance Inflation Factor (VIF)** values for all indicators were below 3.0, indicating no multicollinearity issues. This confirms that the measurement model satisfies the essential psychometric properties required for hypothesis testing.

2.6 Ethical Considerations

The research adheres to ethical standards in data collection and confidentiality. All respondents were informed that their participation was voluntary, and the collected data would be used solely for academic purposes.

Organizational identities were anonymized to prevent disclosure of proprietary cost structures or operational details.

Summary:

The methodological design of this study ensures both analytical robustness and contextual relevance. By combining SEM–PLS analysis with industry-specific indicators, the model effectively captures the complex interplay between structural market inefficiencies and operational imbalances that drive trucking costs in Indonesia.

3. Result and Discussion

3.1 Overview of Model Estimation

The PLS–SEM analysis yielded statistically robust results, confirming both hypothesized relationships between the independent variables—**load imbalance (X₁)** and **market structure distortion (X₂)**—and the dependent variable **trucking cost inefficiency (Y)**. All measurement indicators demonstrated strong reliability and validity, satisfying recommended thresholds for **outer loadings (>0.70)**, **AVE (>0.60)**, and **CR (>0.89)**.

The **structural model** exhibits substantial explanatory power with an **R² value of 0.724**, indicating that 72.4% of the variance in trucking cost inefficiency can be jointly explained by the two determinants. The **Adjusted R² = 0.719** further reinforces the model’s predictive consistency.

Table 1. PLS–SEM Results: Path Coefficients and Significance Levels

Relationship	Path Coefficient (β)	t-Statistic	R ² / AVE / CR	Interpretation
Load Imbalance → Trucking Cost Inefficiency	0.176	2.47	R ² = 0.724	Significant (H1 Supported)
Market Structure Distortion → Trucking Cost Inefficiency	1.278	7.36	AVE = 0.626; CR = 0.893	Highly Significant (H2 Supported)

Source: SmartPLS Output (2025)

3.2 Interpretation of Findings

The results indicate that **market structure distortion** has the most dominant and statistically significant impact on trucking cost inefficiency (β = 1.278, t = 7.36). This implies that structural problems in the trucking market—such as excessive reliance on intermediaries, non-transparent price negotiations, and fragmented competition—are primary drivers of inflated logistics costs.

Conversely, **load imbalance** also has a significant but smaller influence (β = 0.176, t = 2.47), suggesting that while operational inefficiencies matter, they are secondary compared to market-related distortions. This supports the theoretical perspective of **Tirole (1988)**, which posits that market imperfections exert stronger economic distortions than isolated operational inefficiencies.

The high **R² value (0.724)** underscores the combined explanatory power of both structural and operational variables. This finding corroborates **Purnomo (2023)**, who identified a similar pattern in Indonesia’s trucking industry, where both cost distortions and load imbalance interactively determine overall logistics inefficiency.

3.3 Comparative Discussion with Previous Research

When compared to international findings, Indonesia’s results reveal a sharper structural imbalance than those reported in other ASEAN markets. For instance, **Zhang and Jiang (2019)** observed that in China and Vietnam, empty backhaul contributes around 20% of total cost variance, whereas in Indonesia, the combination of load

imbalance and market distortion explains over 70%. This highlights the compounded effect of fragmented competition and logistical asymmetry in developing economies.

Moreover, studies in **Malaysia and Thailand** show that government-regulated freight exchanges have reduced empty runs by 10–15% annually (ASEAN Secretariat, 2022). Indonesia's absence of a similar national digital freight platform exacerbates inefficiency, reinforcing the need for a coordinated digitalization policy.

From a theoretical standpoint, these results extend **Industrial Organization theory** into the logistics domain by empirically demonstrating how imperfect market structures amplify operational inefficiencies. The dual determinants—structural and operational—should therefore be treated as interdependent, not separate, in logistics policy formulation.

3.4 Policy and Managerial Implications

a. Policy Implications

The study's findings provide critical implications for policymakers aiming to lower national logistics costs:

- 1. Freight Market Reform:**
Regulatory authorities should focus on formalizing brokerage activities and establishing transparent digital freight platforms to reduce price manipulation and asymmetrical information flows. A regulated freight-matching system could also improve fleet utilization by connecting demand and supply more efficiently.
- 2. Digital Integration:**
Investment in integrated logistics information systems is essential to enable *real-time cargo visibility* and *route optimization*. The use of digital freight marketplaces has been shown in other ASEAN countries to reduce empty runs and improve transport productivity.
- 3. Regulatory Coordination:**
Current logistics governance in Indonesia is fragmented among multiple agencies. Consolidation under a single *National Freight Coordination Council* could align infrastructure, licensing, and pricing regulations under a unified policy framework.
- 4. Incentive Mechanisms:**
Fiscal incentives, such as tax deductions for operators adopting digital freight technologies or multi-axle vehicles, could accelerate modernization and reduce per-unit transport costs.

b. Managerial Implications

For logistics firms and trucking operators, the findings suggest several actionable strategies:

- 1. Collaborative Load Matching:**
Operators should leverage partnerships or digital alliances to share load data and reduce empty mileage. Digital consolidation of loads across companies can increase fleet productivity by 20–25%.
- 2. Performance-Based Contracting:**
Shippers can mitigate cost inefficiency by shifting toward performance-based contracts that reward on-time delivery and fuel efficiency rather than fixed tariffs.
- 3. Data-Driven Route Planning:**
Adoption of *AI-based route optimization* and predictive analytics can help balance outbound–inbound load ratios, minimizing empty backhauls.

4. Professionalization of Brokerage:

Rather than eliminating intermediaries entirely, professional certification of freight brokers could standardize pricing and improve transparency.

3.5 Synthesis of Empirical Insight

Overall, the analysis reveals a *dual causality* within Indonesia's trucking inefficiency:

- Structural distortions (institutional and market-based) create systemic cost escalation.
- Operational inefficiencies (load imbalance) amplify this effect by lowering asset productivity.

Addressing either determinant in isolation is insufficient; sustainable efficiency requires an integrated reform combining **market restructuring, digital transformation, and regulatory harmonization**.

This study thus provides empirical support for policy models promoting *digital freight platforms, transparent pricing systems, and coordinated governance* as the foundation for a competitive and cost-efficient logistics industry.

4. Conclusions

This study contributes to the empirical understanding of cost inefficiency within Indonesia's trucking logistics sector by integrating two critical determinants: **market structure distortion** and **load imbalance (empty backhaul)**. Using a quantitative approach and **Partial Least Squares–Structural Equation Modeling (PLS–SEM)** with 103 valid industry responses, the findings reveal that both factors significantly increase trucking costs, with **market structure distortion ($\beta = 1.278$)** exerting a stronger effect than **load imbalance ($\beta = 0.176$)**. The model's **R² value of 0.724** confirms high explanatory power, signifying that these two determinants jointly explain 72.4% of the variation in cost inefficiency.

Theoretically, this study extends **Industrial Organization theory** into the logistics domain by empirically validating how fragmented markets and unbalanced trade flows shape transport cost dynamics in a developing economy context. Practically, the findings emphasize that resolving Indonesia's logistics inefficiency requires a *dual-pronged strategy*—structural reform through **market liberalization and regulatory alignment**, coupled with operational improvement via **digital load consolidation and route optimization**.

From a policy perspective, these results provide a foundation for national freight governance reform. Implementing digital freight-matching systems, professionalizing brokers, and harmonizing multi-agency regulations can reduce cost asymmetry and promote equitable competition. For logistics managers, integrating data-driven route planning and collaborative load-sharing strategies could enhance fleet utilization and sustainability. Future research may explore multi-country comparisons within ASEAN or examine how digital adoption mediates the relationship between market distortion and cost efficiency.

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