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frontiers in Future Transportation

TYPE Original Research
PUBLISHED 21 July 2026
DOI 10.3389/ffutr.2026.1884428

OPEN ACCESS

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RECEIVED 18 May 2026
REVISED 22 June 2026
ACCEPTED 29 June 2026
PUBLISHED 21 July 2026

CITATION
Shojaei SA, Pakgohar A and Orouji M (2026) Insurance-market depth and logistics performance in OECD countries: a comparative institutional association. *Front. Future Transp.* 7:1884428. doi: 10.3389/ffutr.2026.1884428

Insurance-market depth and logistics performance in OECD countries: a comparative institutional association

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This study examines whether insurance-market depth is associated with national logistics performance in OECD countries. Logistics-performance research usually emphasises customs, infrastructure, trade facilitation and logistics-service capability, while the broader insurance-market conditions under which freight and supply-chain risks are transferred remain underexamined. Using a balanced panel of 33 OECD countries across four Logistics Performance Index (LPI) waves, 2012, 2014, 2016 and 2018, the study links overall LPI and its six components to insurance density, insurance penetration, retention ratio and non-life insurance share. LPI-wave fixed-effects models with country-clustered standard errors show that logged total insurance density is positively associated with overall LPI and all six LPI components across countries. However, strict country and LPI-wave fixed-effects models do not show a significant within-country relationship. Insurance penetration, retention ratio and non-life insurance share also provide no robust positive evidence once insurance-market depth is considered. The findings therefore support a comparative institutional association: countries in the current-OECD sample with deeper insurance markets tend to have stronger logistics performance, but the evidence does not show that increases in insurance density within a country directly cause logistics-performance improvements. The study contributes by identifying insurance-market depth as an overlooked institutional correlate of logistics performance and by distinguishing insurance density from penetration, retention and market composition.

KEYWORDS
insurance-market depth, logistics performance, logistics performance index (LPI), OECD countries, operational resilience, risk transfer, supply-chain continuity

1 Introduction

Logistics performance is usually explained through infrastructure quality, customs efficiency, trade facilitation, digital connectivity and the competence of logistics-service providers (İnaç et al., 2025). These factors are central to supply-chain performance, but they do not fully capture the institutional conditions that allow firms to move goods under uncertainty. International shipments, warehousing, cargo handling, transport operations and delivery commitments are exposed to accidents, liability claims, natural hazards, documentation failures and business-interruption losses. These exposures are not abstract financial risks; they are everyday operational hazards of freight movement,

including cargo damage in transit, carrier liability after an accident, warehouse loss, shipment delay and delivery failure after disruption. Freight and supply-chain risks are partly managed through cargo insurance, marine insurance, carrier-liability cover, warehouse and property insurance, trade-credit insurance and business-interruption insurance. Yet logistics-performance research has rarely examined whether countries with deeper insurance markets also display stronger logistics performance. This is the gap addressed in this study. In this limited sense, the insurance–logistics relationship is a freight-logistics question as well as a financial-development question: cargo damage, carrier liability, warehouse loss, delayed delivery and business interruption are operational logistics risks, but they are partly managed through financial risk-transfer contracts. Although insurers do not operate ports, clear customs or manage delivery networks, they provide risk-transfer mechanisms that can protect assets, support contractual confidence, enable trade finance and improve recovery after disruption. In this sense, insurance-market depth may complement the conventional logistics determinants captured by the World Bank LPI, which evaluates customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness (World Bank, 2023). The central issue is therefore not whether insurance replaces logistics infrastructure, but whether deeper insurance markets are associated with stronger logistics performance by supporting the risk-transfer capacity needed for continuity, resilience and recovery in supply chains.

This article addresses this issue by examining the insurance-LPI nexus in OECD countries. The OECD setting is appropriate because many member economies already possess relatively mature infrastructure and regulatory systems; therefore, differences in logistics performance may depend not only on physical capacity but also on institutional quality, service sophistication and risk-transfer capacity (OECD, 2015). The study distinguishes insurance density from insurance penetration. Density captures the level of insurance use *per capita* and is interpreted as a proxy for market depth, while penetration captures premiums relative to GDP and may reflect a different relationship between the insurance sector and the size of the economy (Shojaei, 2021). This distinction is consistent with established insurance-economics literature. Skipper (1997) conceptualizes insurance as an institution that supports productive activity through risk transfer, loss prevention, capital allocation and contractual certainty. Enz (2000) further demonstrates the income-related S-curve relationship between insurance penetration and economic development, suggesting that penetration should not be treated as a simple functional measure of insurance-market capacity. The empirical analysis uses a balanced panel of 33 OECD countries observed in four LPI waves: 2012, 2014, 2016 and 2018. Because the panel spans only four LPI waves, the study's empirical leverage is primarily cross-sectional. The analysis is therefore best characterized as a comparative institutional association study rather than a dynamic test of whether insurance-market growth causes logistics improvements over time. The analysis links the overall LPI and its six components to insurance density, insurance penetration, retention ratio and non-life insurance share. GDP *per capita* is used as the baseline control, while augmented robustness specifications for overall LPI additionally include trade openness and rule of law. Accordingly, the study examines whether countries with deeper insurance markets tend to display stronger logistics performance and whether this relationship survives alternative specifications and econometric checks. Three research questions guide the analysis (RQ1) Is insurance-market depth, measured by insurance density, associated with national logistics performance (RQ2) Does the relationship hold uniformly across the six LPI sub-components, or is it concentrated in particular dimensions (RQ3) Does the association reflect between-country differences, within-country dynamics, or both?

The research makes three contributions. First, it reframes insurance-market depth as a comparative institutional correlate of logistics performance rather than treating insurance only as a financial-development variable. Specifically, it examines whether countries with deeper insurance markets also report stronger performance in customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness. Second, it distinguishes insurance density from insurance penetration, retention ratio and non-life insurance share, showing that these measures should not be treated as interchangeable indicators of insurance-market development. Third, it provides OECD evidence that the insurance-LPI relationship is primarily between-country rather than within-country in nature. The study therefore identifies insurance-market depth as part of a wider institutional environment associated with stronger logistics systems, while recognizing that within-country causal claims require longer panels and stronger identification strategies.

2 Literature review and hypothesis development

2.1 Logistics performance, LPI and supply-chain capability

Logistics performance is a multidimensional construct. It reflects not only the availability of roads, ports, airports and digital systems, but also the administrative and service conditions that allow goods to move predictably across borders and within domestic markets. The World Bank's LPI captures this multidimensionality through six components: customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness (Lu et al., 2024). These components correspond to both input-side conditions, such as infrastructure and service quality, and output-side outcomes, such as shipment reliability and timely delivery. The empirical logistics literature consistently shows that better logistics performance is linked to stronger trade outcomes. Haralambides et al. (2026) show that logistics performance affects bilateral trade through cost, time and reliability channels. Martí et al. (2014) examine the importance of LPI components in international trade and demonstrate that logistics performance matters for trade flows. Gani (2017) similarly reports that overall logistics performance and disaggregated logistics measures are positively associated with exports and imports. Puertas et al. (2014) provide European evidence that logistics performance supports export competitiveness. The foundational trade-facilitation literature also shows that logistics costs, border procedures and trade-related administrative frictions shape trade flows and market access

(Wilson et al., 2005; Hoekman and Nicita, 2011). More broadly, OECD evidence links logistics performance to regulatory quality, coordination, automation and trade-facilitation reforms (OECD, 2015). These studies confirm that logistics performance is institutionally embedded and cannot be reduced to physical infrastructure alone. Most of this literature, however, focuses on logistics-specific or trade-facilitation determinants. Infrastructure quality, customs efficiency, shipment procedures and logistics services are usually treated as the direct foundations of performance. This is reasonable, but incomplete. Supply chains also depend on mechanisms that make risk acceptable. A firm may be reluctant to export, import, store inventory or invest in logistics assets if risks cannot be transferred, priced or compensated (Xue et al., 2025). Risk-transfer institutions therefore form part of the broader operating environment within which logistics systems function.

A further reason for using the LPI is that it combines operational and institutional elements. Customs and infrastructure capture formal and physical conditions, while logistics competence, tracking and tracing, and timeliness capture service quality and reliability. The index is therefore suitable for this study because insurance is expected to work indirectly through a broad ecosystem rather than through a single observable channel. A developed insurance market may not improve customs clearance by itself, but it may coexist with institutional environments where firms, regulators and logistics providers manage risk more effectively (Pradhan et al., 2023). The LPI literature also implies that performance gaps are multidimensional (Bayraktar et al., 2025). A country can perform well in timeliness but less well in customs, or have strong infrastructure but weaker international shipment arrangements. For this reason, the study does not stop with the overall LPI score. It also tests each component separately. This is important because the insurance mechanism may plausibly be stronger for some logistics dimensions than for others. For example, tracking and tracing may be associated with higher-value shipments and better risk monitoring, while infrastructure may depend on investment conditions that are also supported by insurance-market depth (Arvis et al., 2023).

2.2 Insurance markets, risk transfer and operational supply-chain continuity

Insurance can support economic activity through two related channels. The financial-intermediation channel concerns savings mobilization, investment and capital allocation. The risk-transfer channel concerns loss absorption, indemnification and the reduction of uncertainty. Arena (2008) finds evidence that insurance market activity can contribute to economic growth. Dawd and Benlagha (2023) also examine dynamic relationships between insurance and growth in OECD countries, while Outreville (2013) reviews the broader insurance-development literature. These studies establish insurance as more than a sectoral financial activity; it is part of the institutional environment of economic performance. The logistics relevance of insurance arises primarily from the risk-transfer channel. Supply chains face operational disruptions, cargo loss, transport accidents, liability exposures, natural hazards and trade-credit failures. Insurance can reduce the consequences of such risks by supporting recovery, stabilizing cash flows, and enabling firms and logistics providers to undertake transactions that would otherwise appear too risky (Xue et al., 2025). This logic is compatible with supply-chain risk management research, which emphasises the importance of resilience, robustness and recovery capability (Ivanov, 2026; Al-Khatib, 2025). During major disruptions, the viability of supply networks depends not only on physical redundancy and operational flexibility, but also on financial and institutional mechanisms that allow systems to survive and recover (Ivanov and Dolgui, 2020). The wider supply-chain resilience research confirms this. Christopher and Peck (2004) emphasise resilience as a capability built through supply-chain design, collaboration, agility and risk awareness, while Tang (2006) highlights robust strategies for mitigating supply-chain disruptions. These works provide the theoretical basis for treating national risk-transfer institutions as part of the wider resilience architecture, distinct from but complementary to firm-level mitigation strategies.

The insurance sector may therefore be interpreted as risk-transfer infrastructure. It does not directly clear customs or operate warehouses, but it can support the continuity of trade and logistics activities. A developed insurance market can signal the presence of actuarial capacity, underwriting expertise, claims-handling capability, reinsurance access and institutional confidence (Shojaei, 2021). These features may be especially relevant in OECD economies, where logistics performance is already relatively high and differences may depend on institutional depth rather than only basic infrastructure availability. Insurance may also affect supply chains by shaping behaviour before a disruption occurs. The existence of insurance products encourages risk assessment, documentation, loss prevention and compliance with safety standards (Dawodu et al., 2026). Underwriters often require information about assets, routes, storage conditions, liability exposures and control systems. These requirements can improve managerial attention to logistics risks even before claims occur. In this sense, insurance is not only a post-loss compensation mechanism; it can also be an ex ante governance mechanism that encourages better risk visibility and operational discipline (Nakata, 2015).

Three conceptual channels may explain why insurance-market depth and logistics performance could be associated across countries. The first is the financial risk-transfer mechanism, which concerns loss absorption and recovery. Insurance can compensate cargo loss, transport accidents, liability claims and business-interruption events, which may help firms and logistics providers manage recovery after disruption (Lei et al., 2026). The second is the institutional trust mechanism, which operates through the legal, actuarial and contractual infrastructure associated with mature insurance markets, including claims-enforcement systems, actuarial data capacity, reliable intermediaries and a culture of contractual certainty (Skipper, 1997; Bah and Abila, 2024; Pradhan et al., 2023). The third is the operational discipline mechanism, which arises from underwriting, risk surveying and claims-documentation requirements (Dawodu et al., 2026; Nakata, 2015). Insurers may require documentation, route disclosure, safety compliance, asset information and tracking data, thereby encouraging logistics-risk governance before claims occur. These mechanisms are not mutually exclusive, but they are conceptually distinguishable. The empirical distinction between insurance density, penetration and non-life share is consistent with this

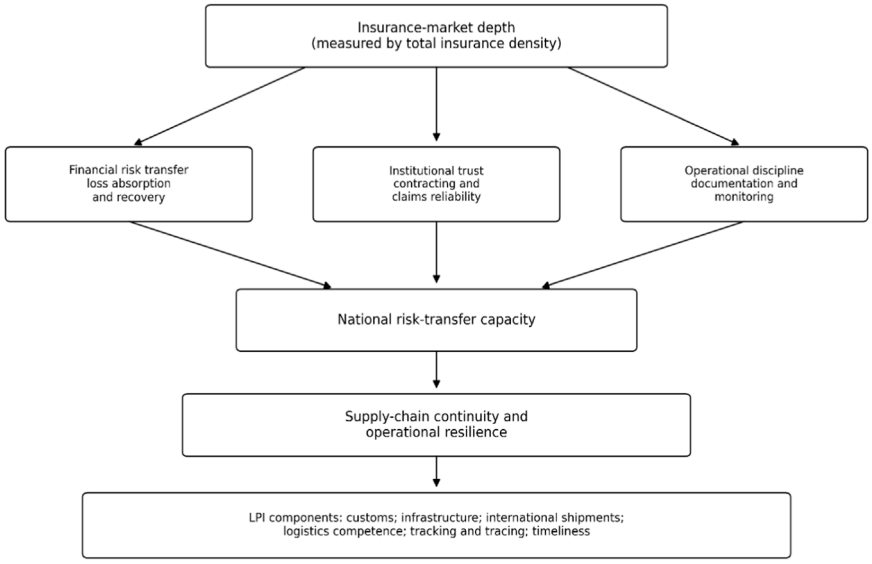

FIGURE 1
Conceptual association between insurance-market depth and logistics performance. Note. The figure presents conceptual channels for the observed cross-country association; the empirical analysis does not directly observe firm-level insurance use, freight-specific coverage or causal mechanisms.

mechanism-based argument: insurance density is more likely to reflect the absolute scale, practical availability and institutional maturity of risk-transfer capacity, whereas penetration and non-life share may capture broader or more aggregated aspects of insurance-market structure. This interpretation is compatible with institutional theory. Countries with deeper insurance markets are likely to have stronger legal enforcement, better data availability, more sophisticated intermediaries and greater trust in contractual arrangements (Bah and Abila, 2024). Figure 1 summarizes the conceptual channels through which insurance-market depth may be associated with logistics performance and distinguishes the proposed conceptual pathway from the empirical association tested in the study.

2.3 Insurance-market depth and logistics performance

A key distinction in the insurance-LPI relationship concerns the meaning of insurance-market depth. Insurance density reflects the amount of insurance premium written per person and can therefore be interpreted as an indicator of the scale and practical use of insurance services in an economy (Tomeski, 2025). In logistics contexts, deeper insurance markets are likely to be associated with broader access to cargo insurance, liability insurance, property insurance, business-interruption cover and other risk-transfer products that support trade and transport operations. Market depth may also reflect actuarial sophistication, claims-handling capacity, risk-pricing expertise and the contractual infrastructure required to manage complex commercial risks (Singh et al., 2025). This argument does not imply that insurance directly builds logistics infrastructure or shortens customs procedures. Rather, insurance-market depth may support the conditions under which logistics systems operate reliably (Haipeng et al., 2025). When firms can transfer insurable risks, they may be more willing to engage in international shipments, use formal logistics contracts, invest in traceability systems and maintain continuity after disruption. Accordingly, and consistent with the view that supply-chain continuity and resilience depend on both operational and institutional risk-management capacity, the first hypothesis is articulated as follows:

H1: Insurance-market depth is positively associated with overall logistics performance.

The same logic can be extended to the multidimensional structure of the LPI. The overall LPI combines customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness. Insurance may matter differently across these dimensions, but each component has a plausible risk-transfer connection (Barakat et al., 2023). Customs and international shipments rely on documentation and contractual certainty; infrastructure and logistics competence are linked to asset protection and professional risk management; tracking and tracing reduce information asymmetry in insured movements; and timeliness is affected by the ability of firms to manage and recover from disruption. Therefore, the second hypothesis is:

H2: Insurance-market depth is positively associated with the six LPI components: customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness.

2.4 Insurance penetration as a competing measure of insurance development

Insurance penetration is another widely used measure of insurance development. It is commonly calculated as gross written premiums relative to GDP and indicates the size of the

insurance sector relative to the wider economy. Because penetration is scaled by GDP, it may capture the insurance sector's relative macroeconomic weight rather than the practical availability of insurance services for logistics actors. In principle, higher penetration could indicate a more important insurance sector (Anikwe et al., 2025) and should therefore be associated with stronger logistics performance. This measure is frequently used in insurance-growth research because it expresses insurance activity in relation to economic output. However, penetration and density do not capture the same empirical concept. Penetration can be high due to large premiums relative to GDP, compulsory insurance lines, or costly risk exposure—none of which necessarily reflect deeper market capacity (Okonkwo and Eche, 2019). It may not directly capture the absolute availability, usage and sophistication of insurance services that support logistics operations. For this reason, penetration is treated as a competing insurance-development measure rather than as a duplicate of insurance density. Hence, the third hypothesis is framed as:

H3: Insurance penetration is positively associated with overall logistics performance.

2.5 Retention, insurance structure and specific logistics channels

Beyond market depth and penetration, insurance-sector structure may also matter for logistics performance. The retention ratio captures the extent to which insurers retain risk domestically rather than ceding it to reinsurers. A higher retention ratio may indicate greater domestic underwriting capacity, stronger claims-management capability and closer engagement with local commercial risks (Horvey and Odei-Mensah, 2025). These features may be particularly relevant to tracking and tracing because insured logistics activities require documentation, monitoring and verification of shipments and losses. The expected effect of retention is theoretically ambiguous. Higher domestic retention may indicate stronger local underwriting capacity, closer engagement with domestic commercial risks and greater claims-management capability. However, lower retention does not necessarily indicate weaker risk capacity, because reinsurance can also improve resilience by providing international capital, technical expertise and risk diversification (Li and Shiu, 2025). Therefore, retention should not be interpreted mechanically as superior risk capacity. If domestic risk-retention capacity supports logistics information systems, the association should be visible in tracking and tracing even after broader insurance depth is considered. Given these competing interpretations, the fourth hypothesis is specified as an exploratory association rather than as a one-directional positive expectation:

H4: The insurance retention ratio is associated with tracking and tracing after controlling for insurance-market depth, but the expected direction is theoretically ambiguous because both domestic retention and international reinsurance may support risk-transfer capacity.

The composition of the insurance market may also carry information about the type of risk-transfer capacity available to logistics systems. Non-life insurance is theoretically closer to supply-chain activity because it includes cargo, marine, motor, property, liability and business-interruption lines (Lei et al., 2026). These product lines are directly connected to the operational risks of goods movement—cargo transit, vehicle operation, warehouse storage, trade-credit exposure and business continuity—in ways that life insurance products are not. A higher non-life share therefore signals that a country's insurance market is oriented toward commercial and operational risk rather than long-term savings and mortality protection. Because non-life share is a compositional measure, its association with logistics performance is only meaningful when overall insurance depth is sufficient to make coverage practically available to logistics firms, leading to the fifth hypothesis:

H5: The non-life insurance share is positively associated with overall logistics performance after controlling for insurance-market depth.

2.6 Within-country dynamics and the limits of cross-country association

While insurance-market depth may explain differences in logistics performance across countries, its relevance can also be examined from a dynamic within-country perspective. Insurance performs economic functions by transferring and indemnifying risk, supporting financial intermediation and enabling firms to manage uncertainty more efficiently (Arena, 2008; OECD, 2025). From a supply-chain perspective, stronger risk-management capacity can support continuity, resilience and recovery after disruption (Fan and Stevenson, 2018). Therefore, if insurance-market depth strengthens the risk-transfer capacity available to firms, logistics providers and trade-related intermediaries, increases in insurance density within a country are expected to be associated with improvements in logistics performance over time. Because insurance-market depth reflects institutionalized risk-transfer capacity rather than a short-term operational input, its within-country relationship with logistics performance is likely to emerge gradually. Improvements in underwriting capacity, claims systems, contractual confidence and logistics-risk governance may require time before they are reflected in national logistics outcomes. Therefore, examining within-country changes provides a stricter and more conservative test of whether insurance-market depth is associated not only with cross-country differences in logistics performance, but also with improvements within the same country over time. Because the panel contains only four LPI waves, this specification is treated as a stricter within-country diagnostic rather than as the main test of the theory, which provides the basis for H6:

H6: In a stricter country and year fixed-effects specification, within-country changes in insurance-market depth are associated with within-country changes in overall logistics performance.

3 Methodology

3.1 Data and sample

The empirical analysis uses a country-year panel constructed from three publicly available datasets. Logistics performance data are sourced from the World Bank LPI for waves 2012, 2014,

TABLE 1 Descriptive statistics.

Variable	N	Mean	Std. Dev	Min	P25	Median	P75	Max
LPI_Overall	132	3.583	0.402	2.612	3.308	3.677	3.915	4.226
LPI_Customs	132	3.401	0.459	2.208	3.113	3.457	3.792	4.208
LPI_Infrastructure	132	3.570	0.524	2.318	3.184	3.721	4.014	4.439
LPI_International_Shipments	132	3.420	0.337	2.550	3.194	3.467	3.653	4.235
LPI_Logistics_Competence	132	3.567	0.438	2.529	3.207	3.676	3.935	4.311
LPI_Tracking_Tracing	132	3.633	0.430	2.549	3.346	3.696	4.005	4.378
LPI_Timeliness	132	3.922	0.378	2.874	3.696	4.008	4.200	4.796
ln_Total_Density	132	7.077	2.025	0.000	6.109	7.506	8.296	10.859
Total_Penetration	132	6.776	6.925	0.000	2.500	5.150	8.625	45.000
Retention_Ratio	132	83.401	20.919	0.000	82.950	88.400	93.150	99.500
NonLife_Insurance_Share	130	49.317	21.585	0.000	34.175	49.127	63.372	92.574
GDP_pc_k	132	39.952	18.622	9.684	26.155	39.108	49.370	116.786
Trade_Openness	132	88.640	58.214	24.730	55.420	73.815	105.260	382.450
Rule_of_Law	132	1.162	0.594	−0.312	0.846	1.281	1.637	2.098

GDP_pc_k is the baseline control variable. Trade_Openness and Rule_of_Law are used in the augmented robustness specifications. NonLife_Insurance_Share has 130 observations because the ratio is mathematically undefined for two country-year observations in which total premiums were zero-coded during data cleaning; these values were not imputed.

2016 and 2018 (World Bank, 2023). The 2023 LPI wave is excluded for reasons of data coverage and temporal-methodological consistency. First, the harmonized insurance-market data used in this study are available only through 2021, which prevents consistent matching of the 2023 LPI wave with the insurance variables. Second, the 2023 LPI edition introduced additional supply-chain tracking indicators based on container, air-cargo and postal data alongside the traditional survey-based LPI framework (Arvis et al., 2024). Therefore, merging the 2012–2018 LPI panel with the 2023 LPI wave would compromise methodological comparability. Insurance variables—total insurance density, total insurance penetration, retention ratio and non-life insurance share—are sourced from the OECD Insurance Statistics database (OECD, 2025), harmonized to USD-denominated values for cross-country comparability. GDP *per capita* and trade openness are sourced from the World Bank World Development Indicators known as WDI (World Bank, 2024), and the rule-of-law index is sourced from the Worldwide Governance Indicators (Kaufmann et al., 2024).

A natural refinement would be to isolate insurance lines most directly relevant to freight logistics, such as marine, aviation and transport insurance, cargo insurance, carrier-liability cover, warehouse insurance, trade-credit insurance and business-interruption insurance. However, these logistics-specific line-of-business variables are not consistently available in a harmonized OECD country-year panel matching the LPI waves used in this study. Total insurance density is therefore used as a national proxy for the overall scale and maturity of insurance-market activity and risk-transfer capacity, as established in the literature (Arena, 2008). This measure should not be interpreted as a direct measure of freight-insurance availability. Rather, it captures the broader insurance-market capacity from which logistics-specific risk-transfer products are supplied. This is a data limitation, and future research using disaggregated marine, aviation, transport, cargo or liability-insurance data could test the freight-insurance mechanism more directly. Therefore, the empirical measure captures national insurance-market depth, not actual cargo-insurance uptake, marine-insurance availability, logistics-firm coverage, claim frequency or the quality of freight-specific underwriting.

The final panel contains 132 observations representing 33 OECD countries—Australia, Belgium, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, United Kingdom and United States—observed across four waves. Non-life insurance share is available for 130 observations because the ratio is mathematically undefined for two country-year observations in which total premiums were zero-coded during data cleaning; these values were not imputed. Six country-year observations required additional data-cleaning decisions. Slovak Republic 2016 and Slovak Republic 2018 report zero-coded total premiums and zero-coded total insurance density, which are implausible for a mature OECD insurance market and are treated as suspected reporting or processing artefacts; these two observations also explain the undefined non-life insurance share ratio reported in Table 1. Four further observations—Colombia 2012, Costa Rica 2012, Latvia 2012 and Lithuania 2012 — report positive total premiums but total insurance density recorded as 0 in the analysis dataset. Because positive premium volume is reported for these country-years, the zero-recorded density values are interpreted as reporting, harmonization, currency-conversion, rounding or denominator artefacts rather than as evidence of a genuine absence of insurance-market activity. The baseline models

retain all six observations through the ln (1 + x) transformation, while the robustness checks in Section 4.5 and Supplementary Appendix Table A10 report results excluding all six suspected artefact observations. Supplementary Appendix Table A1 documents the raw values, transformed values, source fields and treatment decisions for each case. The traditional survey-based LPI was not collected annually; therefore, an annual panel design is not appropriate. The selected-year panel is suitable for examining cross-country and wave-specific associations, but it limits the ability to test dynamic causal relationships. For this reason, the empirical strategy reports both year fixed-effects estimates and stricter country and year fixed-effects robustness checks.

3.2 Variables

The dependent variables are overall LPI and its six components. The main explanatory variable is insurance-market depth, measured by logged total insurance density. Insurance penetration is included as an alternative insurance-development measure, retention ratio is used in the targeted risk-retention specification, and non-life insurance share captures market composition. GDP *per capita* is used as the baseline control, while trade openness and rule of law are added in augmented robustness specifications. Full variable definitions, sources and transformations are reported in Supplementary Appendix Table A2.

3.3 Empirical specifications

The empirical analysis examines whether insurance-market development is associated with logistics performance across OECD countries. The main model tests the relationship between insurance-market depth and overall logistics performance. Retention ratio and non-life insurance share are not included as general baseline controls; instead, they enter targeted specifications designed to test the risk-retention and market-composition hypotheses. Insurance-market depth is measured by logged total insurance density, while GDP *per capita* is included as the main control variable. The baseline model is specified in Equation 1 as follows:

$$\mathrm{LPI}_{it} = \alpha + \beta \ln\_\mathrm{Total\_Density}_{it} + \gamma \mathrm{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (1)$$

where i denotes the country and t denotes the LPI wave year. LPI_{it} is the overall logistics performance score for country i in year t. $\ln\_\mathrm{Total\_Density}_{it}$ represents insurance-market depth, measured as the natural logarithm of one plus total insurance density. $\mathrm{GDP\_pc\_k}_{it}$ is GDP *per capita* expressed in thousands and controls for the level of economic development. λ_t captures LPI-wave fixed effects, while ε_{it} is the error term. The coefficient of interest is β, which indicates whether deeper insurance markets are associated with higher overall logistics performance. The baseline model is intentionally parsimonious and controls for GDP *per capita* as the main aggregator of national economic development. This choice is acknowledged as a limitation, but it is appropriate given the structure of the dataset: the panel contains only 33 countries observed across four non-annual LPI waves. In such a short OECD panel, many candidate controls—including rule of law, digital infrastructure, infrastructure investment, financial development and institutional quality—are conceptually relevant but highly correlated with income level and with one another. Adding a large set of such controls to the baseline model would risk overfitting, unstable coefficients and multicollinearity (MacKinnon et al., 2023). To address omitted-variable concerns without overloading the baseline specification, the study therefore retains GDP *per capita* in the main models and adds trade openness and rule of law in augmented robustness specifications. The control strategy is therefore intentionally limited and should be interpreted accordingly. GDP *per capita* captures broad economic development, while trade openness and rule of law address two important sources of trade exposure and institutional quality. However, these controls cannot exhaust all country-level determinants of logistics performance. Factors such as infrastructure investment, digital connectivity, port capacity, manufacturing structure, regulatory quality, disaster exposure and financial-sector sophistication may also influence LPI outcomes. The estimated insurance-density coefficient is therefore interpreted as a conditional institutional association, not as a fully isolated insurance-market effect.

The second specification examines whether the insurance-depth relationship applies only to overall LPI or also to specific dimensions of logistics performance. The overall LPI score is therefore replaced by each of the six LPI components (Equation 2):

$$\mathrm{LPI\_Component}_{it} = \alpha + \beta \ln\_\mathrm{Total\_Density}_{it} + \gamma \mathrm{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (2)$$

where $\mathrm{LPI\_Component}_{it}$ refers to one of the six component scores of the LPI: customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness. The remaining terms are defined as in Equation 1. This specification allows the analysis to assess whether insurance-market depth is associated with particular dimensions of logistics performance rather than only with the aggregate LPI score. To distinguish insurance-market depth from insurance-market size relative to the economy, the third specification replaces logged insurance density with total insurance penetration. This alternative model is written in Equation 3 as follows:

$$\mathrm{LPI\_Overall}_{it} = \alpha + \beta \mathrm{Total\_Penetration}_{it} + \gamma \mathrm{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (3)$$

where $\mathrm{Total\_Penetration}_{it}$ measures total insurance premiums as a percentage of GDP for country i in year t. This specification tests whether insurance development measured relative to the size of the economy is associated with overall logistics performance. The inclusion of this model is important because insurance density and insurance penetration capture different aspects of insurance-market development: density reflects insurance activity per person, whereas penetration reflects insurance activity relative to national output. The fourth specification focuses on domestic risk retention and its relationship with the tracking and tracing dimension of logistics performance. Tracking and tracing is selected because it is closely related to shipment visibility, risk monitoring and the ability of firms and logistics providers to follow goods through the supply chain. The first retention model is specified in Equation 4a as follows:

$$\text{LPI\_Tracking\_Tracing}_{it} = \alpha + \beta\text{Retention\_Ratio}_{it} + \gamma\text{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (4a)$$

where $\text{LPI\_Tracking\_Tracing}_{it}$ represents the tracking and tracing score for country i in LPI wave year t. $\text{Retention\_Ratio}_{it}$ captures the share of insurance risk retained domestically rather than transferred to reinsurers. GDP_pc_k_{it} controls for economic development, λ_t captures year fixed effects, and ε_{it} is the error term. The coefficient β indicates whether domestic risk retention is associated with stronger tracking and tracing performance. A second retention model (Equation 4b) then adds insurance-market depth to examine whether the retention relationship remains after accounting for the broader development of the insurance market:

$$\text{LPI\_Tracking\_Tracing}_{it} = \alpha + \beta\text{Retention\_Ratio}_{it} + \delta\ln\text{\_Total\_Density}_{it} + \gamma\text{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (4b)$$

where $\text{LPI\_Tracking\_Tracing}_{it}$ again represents the tracking and tracing score for country i in year t. $\text{Retention\_Ratio}_{it}$ captures domestic risk retention, while $\ln\text{\_Total\_Density}_{it}$ captures overall insurance-market depth. GDP_pc_k_{it}, λ_t, and ε_{it} retain the same meanings as in the previous equations. This specification tests whether the retention ratio has an independent association with tracking and tracing after controlling for the broader depth of the insurance market. The fifth specification examines whether the composition of the insurance market matters for logistics performance. Because non-life insurance is more closely connected to cargo, property, liability, transport and business-continuity risks, the model includes non-life insurance share together with insurance-market depth (Equation 5):

$$\text{LPI\_Overall}_{it} = \alpha + \beta\text{NonLife\_Insurance\_Share}_{it} + \delta\ln\text{\_Total\_Density}_{it} + \gamma\text{GDP\_pc\_k}_{it} + \lambda_t + \varepsilon_{it} \quad (5)$$

where $\text{NonLife\_Insurance\_Share}_{it}$ measures the proportion of total insurance premiums accounted for by non-life insurance in country i and year t. $\ln\text{\_Total\_Density}_{it}$ controls for the overall depth of the insurance market, while GDP_pc_k_{it} controls for economic development. λ_t captures year fixed effects and ε_{it} is the error term. This model tests whether the non-life orientation of the insurance market contributes to logistics performance beyond the general level of insurance-market depth. Finally, a stricter within-country specification is estimated by adding country fixed effects to the baseline model. This model examines whether changes in insurance-market depth within the same country are associated with changes in overall logistics performance over time (Equation 6):

$$\text{LPI\_Overall}_{it} = \alpha + \beta\ln\text{\_Total\_Density}_{it} + \gamma\text{GDP\_pc\_k}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (6)$$

where μ_i represents country fixed effects, which control for time-invariant country characteristics such as geography, legal tradition, long-standing institutional capacity and structural features of national logistics systems. λ_t continues to capture year fixed effects.

A concern in cross-country panel regressions of this type is reverse causality: countries with better logistics performance may generate higher trade volumes and economic complexity, which in turn support deeper insurance markets. Several features of the empirical design partially mitigate this concern. First, the lagged specification uses insurance density from the prior LPI wave to predict subsequent LPI performance, reducing, though not removing, contemporaneous simultaneity. Second, the Mundlak decomposition separates between-country and within-country effects. The non-significant within-country coefficient reduces concern that the result is driven solely by short-run simultaneity, although it does not rule out reverse causality operating through persistent between-country differences. Third, the OECD sample is composed of high-income, institutionally stable countries where dramatic simultaneous shifts in both insurance density and LPI are unlikely within any 2-year wave period. These features partially reduce simultaneity concerns, although they do not eliminate reverse-causality risk.

3.4 Econometric checks

The analysis includes several diagnostic and model-selection tests. Following the literature (Shojaei, 2023), multicollinearity is assessed using correlations and variance inflation factors. Year and country fixed-effects F-tests are used to evaluate time and country heterogeneity. A Breusch-Pagan LM test is used to assess panel effects, while a Hausman test compares fixed and random effects. Heteroskedasticity is examined using Breusch-Pagan/Koenker and White tests (Breusch and Pagan, 1979; White, 1980). Serial correlation is assessed using a Wooldridge-style test suitable for panel settings, while cross-sectional dependence is assessed using a Pesaran CD test (Pesaran, 2004; Wooldridge, 2010). Residual normality is examined with the Jarque-Bera test, and functional form is assessed using Ramsey RESET (Ramsey, 1969). Because the panel has only four LPI waves, panel unit-root tests and dynamic GMM estimation are not reported. The reporting strategy follows the logic of cumulative evidence. Robustness checks addressing control specification, inference sensitivity and sample composition are reported separately in Section 4.5.

3.5 Reproducibility and data availability

Because all variables are constructed from public datasets, the replication materials are provided as supplementary files. The replication package includes the country-year dataset, variable-construction rules, data-source identifiers, transformation procedures, and the statistical code used to estimate the baseline, component-level, robustness, lagged, within-between and restricted-sample models. The treatment of zero-coded and zero-recorded insurance-density observations is documented in Supplementary Appendix Table A1. The replication package also identifies the observations excluded from each restricted-sample specification so that the data-cleaning decisions can be independently reproduced.

TABLE 2 Main regression results and hypothesis tests.

Hyp	Dv	Key variable	Coef	Clust. Se	p	CI low	CI high	R^2	Decision
H1	LPI overall	ln_Total_Density	0.104	0.024	<0.001	0.054	0.153	0.548	Conditionally supported
H1 robustness: Composition model	LPI overall	ln_Total_Density	0.124	0.025	<0.001	0.074	0.175	0.570	Conditionally supported
H3	LPI overall	Total_Penetration	−0.003	0.012	0.771	−0.027	0.020	0.423	Rejected
H4 unadjusted	Tracking and tracing	Retention_Ratio	0.007	0.001	<0.001	0.005	0.009	0.450	Positive before depth
H4	Tracking and tracing	Retention_Ratio	−0.001	0.004	0.776	−0.008	0.006	0.511	Not independent of depth
H5 unadjusted	LPI overall	NonLife_Insurance_Share	−0.004	0.002	0.125	−0.009	0.001	0.453	Not supported
H5	LPI overall	NonLife_Insurance_Share	−0.002	0.002	0.452	−0.006	0.003	0.570	Not supported
H5 ΔR^2	LPI overall	Added explanatory power	0.006	F = 1.825	0.179	--	--	--	Not supported
H6	LPI overall	ln_Total_Density	0.007	0.016	0.674	−0.025	0.039	0.921	Within-country: Not supported

4 Results

4.1 Descriptive statistics

Table 1 reports descriptive statistics for the main variables. Overall LPI has a mean of 3.583 and a standard deviation of 0.402, indicating that the sample consists mostly of relatively high-performing OECD logistics systems, but with meaningful variation across countries and years. Among the LPI components, timeliness has the highest mean, while customs and international shipments are comparatively lower. Logged total insurance density has substantial dispersion, reflecting cross-country differences in insurance-market depth. GDP *per capita* also varies widely, confirming the need to control for economic development level.

The descriptive evidence also shows why transformation and careful model specification are needed. Total penetration has a high standard deviation relative to its mean and includes large values in some country-years, while logged density remains more stable after transformation. Retention ratio is generally high in the sample, but it also includes extreme low observations, suggesting that it should not be used mechanically as a main control. These patterns support the decision to use logged density as the central variable and retention as a robustness or targeted hypothesis variable.

4.2 Correlation and multicollinearity

Correlation and VIF diagnostics are reported in Supplementary Appendix Table A3. The diagnostics do not indicate serious multicollinearity in the main model: the VIF for both ln_Total_Density and GDP_pc_k is 2.058. The correlation between overall LPI and logged total insurance density is positive and strong, while the correlation between LPI and insurance penetration is weaker. These preliminary diagnostics support the decision to treat insurance density and insurance penetration as distinct indicators of insurance-market development.

4.3 Hypothesis tests

Table 2 presents the main hypothesis tests using country-clustered standard errors, with wild cluster bootstrap p-values reported separately in Supplementary Appendix Table A9. H1 is conditionally supported. Logged total insurance density has a positive and statistically significant coefficient in the LPI-wave fixed-effects (b = 0.104, p < 0.001, 95% CI [0.054, 0.153]). The relationship remains positive in the composition model that adds non-life insurance share (b = 0.124, p < 0.001, 95% CI [0.074, 0.175]). These results suggest that countries with deeper insurance markets tend to have stronger overall logistics performance. The component-level test for H2 is reported separately in Section 4.4 and Table 3. H3 is rejected. Total insurance penetration has a small negative coefficient and is statistically insignificant (b = −0.003, p = 0.771, 95% CI [-0.027, 0.020]). This result is theoretically useful because it supports the distinction between insurance density and penetration. In this dataset, the absolute depth of insurance use is more informative than the insurance sector's premium volume relative to GDP. The exploratory H4 is not supported in the adjusted specification. Retention ratio is positive and significant in the standalone model predicting tracking and tracing, but it becomes insignificant after ln_Total_Density is added as a control for overall insurance-market depth. This suggests that the apparent retention effect is absorbed once broader insurance-market depth is considered. H5 is also rejected. Non-life insurance share is negative and statistically insignificant in the standalone model and remains negative and insignificant after controlling for insurance depth (b = −0.002, p = 0.452, 95% CI [-0.006, 0.003]). Adding NonLife_Insurance_Share to the model that already includes ln_Total_Density increases R^2 by only 0.006, and the incremental F-test is not significant (F = 1.825, p = 0.179). This indicates that non-life share does not add meaningful explanatory power beyond overall insurance-market depth. The within-country diagnostic test (H6) is not supported. In the strict country and LPI-wave fixed-effects, ln_Total_Density is not statistically significant (b = 0.007, p = 0.674,

TABLE 3 Insurance-market depth and LPI components.

Dependent variable	Key variable	Coefficient	Clustered Se	p-value	CI low	CI high	R^2	Decision
LPI_Customs	ln_Total_Density	0.100	0.028	<0.001	0.045	0.155	0.522	Supported
LPI_Infrastructure	ln_Total_Density	0.131	0.035	<0.001	0.062	0.200	0.528	Supported
LPI_International_Shipments	ln_Total_Density	0.079	0.023	<0.001	0.034	0.125	0.422	Supported
LPI_Logistics_Competence	ln_Total_Density	0.111	0.027	<0.001	0.058	0.165	0.536	Supported
LPI_Tracking_Tracing	ln_Total_Density	0.126	0.023	<0.001	0.081	0.170	0.510	Supported
LPI_Timeliness	ln_Total_Density	0.082	0.019	<0.001	0.044	0.119	0.468	Supported

TABLE 4 Robustness, diagnostics and sensitivity summary.

Robustness or diagnostic check	Detailed table	Key result	Interpretation
Model-selection tests	Supplementary Appendix Table A4	Country effects significant; panel effects present; hausman favors fixed effects	Country heterogeneity matters and pooled OLS is not sufficient
Main diagnostic tests	Supplementary Appendix Table A5	Serial correlation and residual non-normality appear in the main model; no cross-sectional dependence is detected	Robust inference is required
Within-between decomposition	Supplementary Appendix Table A6	Within effect: b = 0.0069, p = 0.629; between effect: b = 0.198, p < 0.001	Association is primarily between countries
Lagged LPI-wave fixed-effects model	Supplementary Appendix Table A7	b = 0.1058, p < 0.001, N = 99	Lagging insurance depth does not change the positive between-country association
Lagged country and LPI-wave fixed-effects model	Supplementary Appendix Table A7	b = 0.0068, p = 0.747, N = 99	Within-country lagged association is not supported
Augmented controls: Trade openness and rule of law	Supplementary Appendix Table A8	b Declines from 0.104 to 0.075 but remains significant	Main association survives additional controls
Wild cluster bootstrap	Supplementary Appendix Table A9	H1 bootstrap p = 0.004; all H2 components remain significant	Results are not sensitive to bootstrap correction
Restricted sample excluding all six suspected artefacts	Supplementary Appendix Table A10	H1 restricted-sample b = 0.106, p < 0.001, N = 126	Main finding is not driven by suspected artefact observations

Detailed results are reported in Supplementary Appendix Tables A4–A10. All main regression specifications include LPI-wave fixed effects and country-clustered standard errors unless otherwise stated. The restricted sample excludes Slovak Republic 2016, Slovak Republic 2018, Colombia 2012, Costa Rica 2012, Latvia 2012 and Lithuania 2012.

95% CI [-0.025, 0.039]). This is an important limitation. The evidence supports a between-country association, but does not provide evidence of a within-country effect over time.

4.4 LPI component-level results

Table 3 reports the component-level results for H2. Logged total insurance density is positive and statistically significant for all six LPI components. The largest coefficients are observed for infrastructure (b = 0.131) and tracking and tracing (b = 0.126), followed by logistics competence (b = 0.111), customs (b = 0.100), timeliness (b = 0.082) and international shipments (b = 0.079). These results indicate that the association between insurance-market depth and logistics performance is not limited to the aggregate LPI score. It is visible across both input-oriented and output-oriented dimensions of logistics performance. The component findings are consistent with the interpretation of insurance depth as institutional risk-transfer capacity. Insurance may be most closely connected to tracking and tracing and infrastructure because these areas depend on investment, coordination and confidence in high-value physical and information systems.

4.5 Robustness, diagnostics and sensitivity summary

Table 4 summarizes the main robustness, diagnostic and sensitivity checks, while the detailed results are reported in Supplementary Appendix Tables A4–A10. The model-selection results indicate that country heterogeneity is empirically important. Country effects are statistically significant, panel effects are present, and the Hausman test favors fixed effects, although the result is interpreted cautiously because of the short panel structure. These diagnostics support the decision to report both LPI-wave fixed-effects models, which use the main cross-country variation in the data, and stricter country and LPI-wave

fixed-effects models, which test whether the association also appears within countries over time.

The diagnostic tests provide mixed evidence, which is not unusual in a short macro-panel with substantial cross-country variation. In the main LPI-wave fixed-effects model, residual non-normality and serial correlation are detected, while cross-sectional dependence is not indicated. These results motivate robust inference using country-clustered standard errors and additional wild cluster bootstrap checks. The bootstrap results do not alter the substantive conclusions: the insurance-density coefficient remains significant for overall LPI and all six LPI components, while the unsupported hypotheses remain statistically insignificant. The inference is therefore not driven solely by conventional asymptotic clustered standard errors, although the short panel structure still warrants cautious interpretation.

The within-between decomposition is central to the interpretation of the study. The within-country deviation of logged insurance density is not statistically significant, whereas the country mean of logged insurance density is positive and significant. This confirms that the insurance-LPI association is primarily a between-country relationship. In substantive terms, countries with higher average insurance-market depth tend to have higher average logistics performance, but changes in insurance depth within the same country over the four LPI waves do not significantly explain changes in LPI. This pattern supports the paper's comparative institutional association framing.

The lagged specifications lead to a similar conclusion. Lagged insurance depth remains positive and significant in the LPI-wave fixed-effects model, but it is not significant in the country and LPI-wave fixed-effects model. Lagging the insurance variable therefore reduces contemporaneous simultaneity concerns, but the evidence remains between-country in nature. The findings remain consistent with persistent cross-country institutional differences rather than short-run country-level changes in insurance-market depth.

The augmented-control specifications also support the robustness of the main association. When trade openness and rule of law are added to the baseline model, the coefficient on logged insurance density declines from the baseline estimate but remains positive and statistically significant. This reduction is substantively important because it suggests that insurance-market depth is partly embedded in a wider institutional capability bundle that includes trade exposure and legal-institutional quality. However, the coefficient does not disappear, indicating that the main association is not fully absorbed by these additional controls.

Finally, the restricted-sample analysis shows that the findings are not driven by the six suspected artefact observations documented in Supplementary Appendix Table A1. Excluding Slovak Republic 2016 and Slovak Republic 2018, which report zero-coded premiums and density, together with Colombia 2012, Costa Rica 2012, Latvia 2012 and Lithuania 2012, which report positive premiums but zero-recorded density, leaves the main conclusion unchanged. The restricted-sample insurance-density coefficient remains close to the full-sample estimate. Taken together, the robustness evidence supports a consistent interpretation: insurance-market depth is positively associated with logistics performance across the sample, with the association operating mainly between countries rather than within countries.

5 Discussion and implications

The findings provide a more differentiated interpretation of the insurance-LPI nexus and its relevance to supply-chain continuity and operational resilience. The evidence does not suggest that all forms of insurance development improve logistics performance. Rather, the main empirical pattern is that countries with deeper insurance markets tend to report stronger overall LPI performance and stronger performance across all six LPI components. This supports the view that resilience is not only a firm-level operational capability, but also a system-level institutional condition. Countries with deeper insurance markets are associated with stronger continuity and operational resilience in logistics systems, reflected in broader access to mechanisms that absorb losses, stabilize transactions and support recovery after disruption. Through mechanisms such as loss absorption, claims settlement, contractual confidence, asset protection and recovery support, insurance-market depth may form part of the wider institutional environment that enables supply chains to withstand and recover from operational disruptions.

This interpretation is strengthened by the contrast between insurance density and other insurance-market indicators. Insurance penetration, retention ratio and non-life insurance share do not provide independent positive evidence once insurance-market depth is considered. This distinction shifts the interpretation away from a general claim that "more insurance" improves logistics performance and toward a more specific market-depth explanation. Insurance penetration measures premiums relative to GDP, whereas insurance density captures the intensity of insurance use per person. In mature OECD economies, density may better reflect the availability, sophistication and practical use of risk-transfer services that support logistics and supply-chain activities. The results therefore suggest that the choice of insurance indicator matters. Insurance density and insurance penetration should not be treated as interchangeable measures when the theoretical mechanism concerns risk-transfer capacity rather than the insurance sector's size relative to the economy.

The component-level results further support this interpretation. The positive association between insurance depth and customs, infrastructure, international shipments, logistics competence, tracking and tracing, and timeliness suggests that insurance-market depth is connected to a broader bundle of institutional and operational capabilities. These may include stronger risk pricing, claims-handling capacity, contractual enforcement, trade-credit availability, asset protection and recovery mechanisms. The relatively strong coefficients for infrastructure and tracking and tracing are also plausible because these dimensions depend on investment, coordination, shipment visibility and confidence in high-value physical and information systems. From a supply-chain continuity and resilience perspective, this implies that logistics resilience depends not only on physical infrastructure and digital systems, but also on institutional arrangements that allow risks to be priced, transferred and managed.

At the same time, the findings should be read as evidence of institutional complementarity. Insurance depth appears to coexist with stronger logistics systems as part of a wider national capability bundle that includes institutional quality, financial sophistication, infrastructure investment, administrative efficiency and logistics-

service maturity. This interpretation is consistent with the country and LPI-wave fixed-effects model and the Mundlak-style decomposition, which indicate that the relationship is mainly between countries rather than within countries over time.

5.1 Interpretation of unsupported and exploratory results

Four tests did not provide supportive evidence in the expected or targeted specification: H3, H4, H5 and H6. This pattern is theoretically informative rather than merely null. First, insurance penetration (H3) was not significantly associated with overall logistics performance. Penetration measures premium volume relative to GDP. In OECD economies, this measure may be influenced by compulsory insurance lines, premium pricing conditions, market structure or GDP denominator effects. These factors do not necessarily capture the practical risk-transfer depth available to logistics actors. The insignificant penetration result therefore supports the distinction between insurance density and insurance penetration rather than undermining the broader argument.

Second, the retention ratio (H4) was positive and significant in the standalone tracking-and-tracing model, but it lost significance once insurance density was included. This suggests that retention and density partly overlap empirically, and that retention does not provide independent explanatory power beyond overall market depth in the current country-level panel. This does not mean that domestic retention is irrelevant. Rather, it suggests that the aggregate retention ratio may be too broad to isolate logistics-related risk capacity, especially because reinsurance relationships can also support resilience by providing international capital, technical expertise and risk diversification.

Third, non-life insurance share (H5) was not significantly associated with overall logistics performance after controlling for insurance-market depth. This result is plausible because non-life insurance share is a compositional variable: it measures the proportion of premiums written in non-life lines, not the absolute volume of non-life coverage available in the economy. A country with a deep and diversified insurance market may have a moderate non-life share while still offering substantial logistics-relevant coverage. Conversely, a country with a high non-life share may still have a relatively thin insurance market in absolute terms. Moreover, the aggregate non-life share does not separately identify cargo, marine, trade-credit, liability, warehouse, property or business-interruption insurance, which are the product lines most directly relevant to logistics and supply-chain resilience.

Fourth, within-country changes in insurance-market depth (H6) were not significantly associated with within-country changes in logistics performance. This does not imply that insurance-market development is irrelevant over time. Rather, it suggests that the relationship between insurance-market depth and logistics performance may operate through slow-moving institutional complementarities among insurance markets, logistics systems, regulatory frameworks, legal enforcement and financial-sector sophistication. The four LPI waves from 2012 to 2018 provide limited within-country variation, while insurance markets in mature OECD economies tend to change gradually. A longer panel with more frequent logistics-performance measures would be better suited to testing within-country dynamics.

5.2 Theoretical implications

The study contributes theoretically by extending the insurance-growth nexus into the domain of logistics and supply-chain performance. Earlier studies have generally examined whether insurance activity is associated with GDP growth or financial development. This article redirects attention to logistics performance as a meso-level economic outcome. The theoretical implication is that insurance should not be viewed only as a financial-sector variable. It can also be conceptualized as a risk-transfer infrastructure that complements trade, logistics and supply-chain systems. A second theoretical implication concerns measurement. Insurance density and insurance penetration are often used interchangeably as indicators of insurance development. The results show that this is problematic. Density is positively associated with LPI, while penetration is not. This indicates that scholars should match insurance measures to theoretical mechanisms. If the mechanism is economy-wide relative importance, penetration may be appropriate. If the mechanism is practical risk-transfer capacity available to firms and households, density may be more suitable. A third implication concerns supply-chain resilience theory. The supply-chain literature often emphasises operational capabilities such as robustness, agility, redundancy and visibility. This study suggests that national insurance-market depth may be part of the institutional context in which those capabilities develop. Risk management in supply chains is not only a firm-level practice; it is also supported by national financial and insurance systems that enable firms to absorb losses, recover from disruptions and maintain confidence in trade relationships.

5.3 Practical and managerial implications

For policymakers, the findings should be used for institutional diagnosis rather than as evidence of a direct policy lever. Countries with deeper insurance markets tend to show stronger logistics performance, but the results do not imply that increasing insurance density will automatically improve LPI scores within a short period. Policy relevance lies in strengthening the wider risk-transfer ecosystem, including contract enforcement, claims reliability, reinsurance access, insurance supervision, logistics-risk documentation and coordination between insurers, shippers and logistics providers.

For insurers, the findings highlight logistics and supply-chain activity as a strategic area of economic relevance. Cargo, marine, trade-credit, liability, warehouse, property and business-interruption insurance can be positioned as part of the institutional architecture that supports trade continuity. However, the evidence does not show that aggregate non-life share or domestic retention alone explains logistics performance. Insurers should therefore emphasise the quality, accessibility and claims reliability of logistics-relevant coverage rather than only premium volume or market share.

For logistics firms and supply-chain managers, the findings suggest that insurance should be considered alongside

operational risk-management tools such as tracking systems, documentation, supplier assessment, route planning and contingency arrangements. The study does not estimate firm-level returns from insurance coverage, but it indicates that logistics systems in countries with deeper insurance markets tend to perform better across LPI dimensions. Insurance should therefore be understood as one element of supply-chain continuity planning, not as a substitute for operational resilience capabilities.

6 Limitations and future research

This study has several limitations. First, the LPI is not annual, so the panel contains only four selected waves. This limits the ability to estimate dynamic models, panel unit-root tests or GMM specifications. The short time dimension also reduces the power of within-country tests. Future research could use the newer LPI 2.0 tracking-data structure or alternative annual logistics indicators if they become available. Second, the study cannot identify a causal insurance-improvement mechanism. Although the research design partially reduces simultaneity concerns, reverse causality cannot be fully excluded: stronger logistics performance may also support deeper insurance markets. The non-significant country and year fixed-effects result further indicates that within-country changes in insurance depth do not explain LPI changes in the current dataset. Future studies should use longer panels and stronger identification strategies, such as instrumental variables, regulatory shocks, market-liberalisation episodes or natural experiments affecting insurance availability. Third, the study uses country-level insurance indicators. This is suitable for a national logistics-performance study, but it cannot identify firm-level mechanisms. Future research could use insurer-level or firm-level data to examine whether companies with better insurance coverage experience fewer logistics disruptions, faster recovery or higher supply-chain reliability. The next limitation concerns the control structure. The baseline model controls only for GDP *per capita*. While this choice is justified by the small sample and high inter-correlation among institutional indicators in OECD countries (Cameron and Miller, 2015; MacKinnon et al., 2023), Supplementary Appendix Table A8 presents augmented specifications adding trade openness and a rule-of-law index, which partially address omitted-variable concerns. However, the models still omit broader factors such as infrastructure investment, digital connectivity, manufacturing intensity, disaster exposure and financial development. This is especially relevant because supply-chain continuity and operational resilience may also depend on environmental exposure, digital capability, governance quality and infrastructure investment. Therefore, the insurance-density coefficient may still partially reflect broader national capability rather than a distinct insurance-market association. Future studies should expand the control structure once reliable and consistent data are collected. A further limitation concerns insurance-line granularity. The study uses total insurance density and non-life insurance share because harmonized country-year data for marine, aviation, transport, cargo, carrier-liability and warehouse-related insurance are not consistently available across the sample. Future research should collect disaggregated logistics-relevant insurance data to test whether these specific lines explain freight logistics performance more directly than aggregate insurance-market depth. Finally, the study focuses on 33 OECD countries. This improves data quality and institutional comparability, but it substantially constrains generalizability. In OECD economies, both insurance markets and logistics systems are relatively mature; the cross-country variation may therefore underestimate the relevance of insurance for countries where logistics infrastructure is weaker, formal risk-transfer markets are thinner and supply-chain disruptions are more frequent and severe. The direction, magnitude and even the sign of the insurance-LPI association may differ in low- and middle-income economies. Researchers applying this framework to non-OECD settings should account for differences in compulsory insurance regimes, reinsurance dependence, informality in logistics operations and the role of state-owned insurers. The OECD findings should not be applied as policy benchmarks for developing economies without explicit re-estimation in those contexts.

7 Conclusion

This article examined whether insurance-market development is associated with national logistics performance. Using a balanced panel of 33 OECD countries across four LPI waves, the study linked World Bank LPI scores with insurance-market indicators. The evidence shows that insurance-market depth is positively associated with overall LPI and with all six LPI components. By contrast, insurance penetration is not significantly associated with LPI. Retention ratio and non-life insurance share do not remain independently significant once market depth is included. The strict within-country fixed-effects model is also not significant. The main conclusion is therefore that countries with deeper insurance markets tend to have stronger logistics performance, but the current data do not prove that increases in insurance depth within a country directly improve logistics performance over time. The paper does not prove that expanding insurance markets causes logistics performance to improve, does not measure freight-specific insurance coverage directly, and does not establish firm-level mechanisms linking insurance contracts to shipment-level outcomes. The paper's contribution lies in identifying insurance-market depth as an overlooked institutional correlate of logistics performance and in showing that the insurance-LPI nexus is better understood through market depth than through simple penetration. The findings open a new research avenue at the intersection of insurance, logistics, and supply-chain resilience. Insurance should be considered not only as a financial-sector outcome or growth determinant, but also as an institutional correlate of the risk-transfer context surrounding trade and logistics systems. Future studies can build on this foundation by adding richer controls, longer data series, causal identification strategies and firm-level mechanisms.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and

accession number(s) can be found in the article/ Supplementary Material.

Author contributions

SS: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. AP: Conceptualization, Data curation, Investigation, Resources, Writing – review and editing. MO: Data curation, Formal Analysis, Methodology, Software, Visualization, Writing – review and editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This research was supported by the Sheffield Hallam University Open Access Fund. For the purpose of open access, the author has applied a Creative Commons Attribution (CC BY) licence to any Author Accepted Manuscript version of this paper arising from this submission.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffutr.2026.1884428/full#supplementary-material

References

Al-Khatib, A. W. (2025). The impact of supply chain transparency and supply chain resilience on supply chain risk management: a moderation effect modeling. *Supply Chain Manag. Int. J.* 30 (5), 566–581. doi: 10.1108/SCM-02-2025-0108

Anikwe, G., Ezema, C. A., and Amobi, O. (2025). Insurance market penetration and business performance: evidence from Nigeria and implications for sustainable development in Africa. *INOSR Arts Manag.* 11 (2), 37–49. doi: 10.59298/INOSRAM/2025/112.3749

Arena, M. (2008). Does insurance market activity promote economic growth? A cross-country study for industrialized and developing countries. *J. Risk Insur.* 75 (4), 921–946. doi: 10.1111/j.1539-6975.2008.00291.x

Arvis, J.-F., Ojala, L., Shepherd, B., Ulybina, D., and Wiederer, C. (2023). Connecting to compete 2023: trade logistics in an uncertain global economy—The logistics performance index and its indicators. *World Bank.* doi: 10.1596/39760

Arvis, J.-F., Ulybina, D., and Wiederer, C. (2024). *From Survey to Big Data: The New Logistics Performance Index (Policy Research Working Paper No. 10772)*. World Bank. Available online at: http://hdl.handle.net/10986/41557 (Accessed May 03, 2026).

Bah, M., and Abila, N. (2024). Institutional determinants of insurance penetration in Africa. *Geneva Pap. Risk Insurance—Issues Pract.* 49, 138–179. doi: 10.1057/s41288-022-00278-2

Barakat, M., Madkour, T., and Moussa, A. M. (2023). The role of logistics performance index on trade openness in Europe. *Int. J. Econ. Bus. Res.* 25 (3), 379–394. doi: 10.1504/IJEBR.2023.129967

Bayraktar, E., Zaim, S., Gudelek, M., and Golgeci, I. (2025). Global logistics efficiency after COVID-19: a cross-country analysis using the logistics performance index. *Int. J. Logist. Res. Appl.*, 1–32. doi: 10.1080/13675567.2025.2540863

Breusch, T. S., and Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica* 47 (5), 1287–1294. doi: 10.2307/1911963

Cameron, A. C., and Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. *J. Hum. Resour.* 50 (2), 317–372. doi: 10.3368/jhr.50.2.317

Christopher, M., and Peck, H. (2004). Building the resilient supply chain. *Int. J. Logist. Manag.* 15 (2), 1–14. doi: 10.1108/09574090410700275

Dawd, I., and Benlagha, N. (2023). Insurance and economic growth nexus: new evidence from OECD countries. *Cogent Econ. and Finance* 11 (1), 2183660. doi: 10.1080/23322039.2023.2183660

Dawodu, A. W., Adeyemo, D. L., and Epetimehin, F. (2026). Insurance pre-loss risk surveying and sustainability underwriting of non-life insurance companies in Nigeria. *Int. J. Financial Res. Bus. Dev.* 11 (7), 1–38. doi: 10.70382/mejfrbd.v11i7.080

Enz, R. (2000). The S-curve relation between per-capita income and insurance penetration. *Geneva Pap. Risk Insur. Issues Pract.* 25 (3), 396–406. doi: 10.1111/1468-0440.00072

Fan, Y., and Stevenson, M. (2018). A review of supply chain risk management: definition, theory, and research agenda. *Int. J. Phys. Distribution and Logist. Manag.* 48 (3), 205–230. doi: 10.1108/IJPDLM-01-2017-0043

Gani, A. (2017). The logistics performance effect in international trade. *Asian J. Shipp. Logist.* 33 (4), 279–288. doi: 10.1016/j.ajsl.2017.12.012

Haipeng, M., Shurui, X., Anqiong, T., and Xiaodong, W. (2025). Optimization of cargo safety liability and insurance legal model under intelligent warehousing environment. *Acad. J. Bus. and Manag.* 7 (11), 97–102. doi: 10.25236/AJBM.2025.071114

Haralambides, H., Akdamar, E., and Akgul, E. F. (2026). Revealing patterns of technology and commerce: evidence from digital competitiveness and logistics performance. *Asian J. Shipp. Logist.* 42 (2), 69–83. doi: 10.1016/j.ajsl.2026.03.001

Hoekman, B., and Nicita, A. (2011). Trade policy, trade costs, and developing country trade. *World Dev.* 39 (12), 2069–2079. doi: 10.1016/j.worlddev.2011.05.013

Horvey, S. S., and Odei-Mensah, J. (2025). Re-examining the microeconomic and macroeconomic determinants of nonlife insurers profitability in South Africa: insights from linear and threshold analysis. *J. Innovation Entrepreneursh.* 14, 30. doi: 10.1186/s13731-024-00461-w

İnaç, H., Ayözen, Y. E., Yelshibayev, R., and Issayeva, G. (2025). An application of logistics performance index-driven policy development to Turkey and Kazakhstan. *J. Knowl. Econ.* 16 (1), 4898–4917. doi: 10.1007/s13132-024-02160-z

Ivanov, D. (2026). Comparative analysis of product and network supply chain resilience. *Int. Trans. Operational Res.* 33 (4), 2358–2376. doi: 10.1111/itor.13612

Ivanov, D., and Dolgui, A. (2020). Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. *Int. J. Prod. Res.* 58 (10), 2904–2915. doi: 10.1080/00207543.2020.1750727

Kaufmann, D., Kraay, A., and Mastruzzi, M. (2024). *Worldwide Governance Indicators*. World Bank. Available online at: https://info.worldbank.org/governance/wgi (Accessed April 20, 2026).

Lei, Y., Zhou, H., and Zhao, Y. (2026). Premium sharing for supply chain coordination with business interruption insurance under supply disruption. *Int. Trans. Operational Res.* 33 (4), 2325–2357. doi: 10.1111/itor.70080

Li, X., and Shiu, Y.-M. (2025). Does reinsurance affect capital structure deviations? Evidence from US property–casualty insurers. *Geneva Pap. Risk Insur. – Issues Pract.* 50, 881–905. doi: 10.1057/s41288-025-00356-1

Lu, X., Zhang, C., and Geng, L. (2024). Impact of logistics performance on international trade: a test based on meta-analysis. *J. Int. Trade and Econ. Dev.* 35 (1), 252–279. doi: 10.1080/09638199.2024.2431263

MacKinnon, J. G., Nielsen, M. Ø., and Webb, M. D. (2023). Cluster-robust inference: a guide to empirical practice. *J. Econ.* 232 (2), 272–299. doi: 10.1016/j.jeconom.2022.04.001

Martí, L., Puertas, R., and García, L. (2014). The importance of the logistics performance index in international trade. *Appl. Econ.* 46 (24), 2982–2992. doi: 10.1080/00036846.2014.916394

Nakata, H. (2015). "On the design of regional insurance markets for east Asia," in *Resilience and Recovery in Asian Disasters: Community Ties, Market Mechanisms, and Governance*. Editors D. P. Aldrich, S. Oum, and Y. Sawada (Springer), 201–216. doi: 10.1007/978-4-431-55022-8_10

OECD (2015). *Drivers of Logistics Performance: A Case Study of Turkey*. OECD Publishing. doi: 10.1787/5jlwvzd3pks2-en

OECD (2025). *Global Insurance Market Trends 2025*. OECD Publishing. doi: 10.1787/0d11ecf4-en

Okonkwo, I. V., and Eche, A. U. (2019). Insurance penetration rate and economic growth in Nigeria: 1981-2017. *Int. J. Soc. Sci. Manag. Rev.* 2 (1), 21–45.

Outreville, J. F. (2013). The relationship between insurance and economic development: 85 empirical papers for a review of the literature. *Risk Manag. Insur. Rev.* 16 (1), 71–122. doi: 10.1111/j.1540-6296.2012.01219.x

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *Camb. Work. Pap. Econ. No.*, 0435. doi: 10.17863/CAM.5113

Pradhan, R. P., Bahmani, S., and Abraham, R. (2023). Institutional quality, insurance markets, and economic growth: evidence from pooled mean group estimation. *Appl. Econ. Lett.* 30 (4), 445–449. doi: 10.1080/13504851.2021.1991561

Puertas, R., Martí, L., and García, L. (2014). Logistics performance and export competitiveness: european experience. *Empirica* 41, 467–480. doi: 10.1007/s10663-013-9241-z

Ramsey, J. B. (1969). Tests for specification errors in classical linear least-squares regression analysis. *J. R. Stat. Soc. Ser. B* 31 (2), 350–371. doi: 10.1111/j.2517-6161.1969.tb00796.x

Shojaei, S. A. (2021). *The Impacts of Diversification Strategy on the Financial Performance of Insurers*. United Kingdom: Sheffield Hallam University.

Shojaei, S. A. (2023). Diversification strategy and financial performance of insurance firms: evidence from Iran. *Int. J. Manag. Account. Econ.* 10 (12), 997–1021. doi: 10.5281/zenodo.10656766

Singh, D., Malik, G., Jha, A., Yadav, A., and Jain, P. (2025). Insurance and economic growth nexus: a comprehensive exploration of the dynamic relationship and future research trajectories. *J. Econ. Surv.* 39 (3), 841–876. doi: 10.1111/joes.12627

Skipper, H. D. (1997). Foreign insurers in emerging markets: Issues and concerns. *Int. Insur. Found. Occas.*

Tang, C. S. (2006). Robust strategies for mitigating supply chain disruptions. *Int. J. Logist. Res. Appl.* 9 (1), 33–45. doi: 10.1080/13675560500405584

Tomeski, B. (2025). Economic, demographic, and institutional drivers of life insurance consumption in Macedonia. *J. Econ. Finance Manag. Stud.* 8 (10), 6614–6626. doi: 10.47191/jefms/v8-i10-05

White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica* 48 (4), 817–838. doi: 10.2307/1912934

Wilson, J. S., Mann, C. L., and Otsuki, T. (2005). Assessing the benefits of trade facilitation: a global perspective. *World Econ.* 28 (6), 841–871. doi: 10.1111/j.1467-9701.2005.00709.x

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data*. 2nd ed. MIT Press.

World Bank (2023). Survey-based LPI (2007–2023). Logistics performance index. Available online at: https://lpi.worldbank.org/en/indicators/survey-based-lpi-2007-2023 (Accessed April 23, 2026).

World Bank (2024). World development indicators. Available online at: https://databank.worldbank.org/source/world-development-indicators (Accessed April 18, 2026).

Xue, Y., Yan, J., Mohsin, M., and Mehak, A. (2025). Supply chain risks in agri-food systems: a comprehensive review of economic vulnerabilities and mitigation approaches. *Front. Sustain. Food Syst.* 9, 1649834. doi: 10.3389/fsufs.2025.1649834