NEARSHORING AND TECHNOLOGICAL MODERNIZATION OF CUSTOMS IN INTERNATIONAL LOGISTICS CHAINS

NEARSHORING E MODERNIZAÇÃO TECNOLÓGICA DAS ADUANAS NAS CADEIAS LOGÍSTICAS INTERNACIONAIS

NEARSHORING Y MODERNIZACIÓN TECNOLÓGICA DE ADUANAS EN CADENAS LOGÍSTICAS INTERNACIONALES

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ABSTRACT

The nexus between nearshoring and customs technological modernization in international logistics chains is analyzed. Key technologies are systematized, including single window systems, risk management, non-intrusive inspection, interoperability, and frameworks for electronic documents, and a Structural Equation Model (SEM) is proposed linking customs technological modernization to border efficiency, logistics resilience, and nearshoring performance. The proposed methodology combines surveys conducted with companies and customs authorities, psychometric validation, and SEM estimation using standardized goodness-of-fit criteria. Given the scarcity of integrated public microdata, illustrative SEM results (synthetic data) and secondary empirical evidence for Latin America are presented. Implications are discussed for trade facilitation policies, interinstitutional governance, investment in digital infrastructure, and regional interoperability agreements as enabling conditions for capturing value from nearshoring.

Keywords: Nearshoring. Trade Facilitation. Digital Customs. Single Window. Risk Management.

RESUMO

Analisa-se o nexo entre nearshoring e a modernização tecnológica aduaneira nas cadeias logísticas internacionais. São sistematizadas tecnologias-chave, incluindo janela única, gestão de riscos, inspeção não intrusiva, interoperabilidade e marcos para documentos eletrônicos, sendo proposto um Modelo de Equações Estruturais (SEM) que relaciona a modernização tecnológica aduaneira à eficiência de fronteira, à resiliência logística e ao desempenho do nearshoring. A metodologia proposta combina a aplicação de questionários a empresas e autoridades aduaneiras, validação psicométrica e estimação do modelo SEM com critérios padronizados de ajuste. Diante da escassez de microdados públicos integrados, são apresentados resultados ilustrativos do SEM (dados sintéticos) e evidências

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empíricas secundárias para a América Latina. Discutem-se implicações para políticas de facilitação do comércio, governança interinstitucional, investimentos em infraestrutura digital e acordos regionais de interoperabilidade como condições habilitadoras para a captura de valor do nearshoring.

Palavras-chave: Nearshoring. Facilitação do Comércio. Aduanas Digitais. Janela Única. Gestão de Riscos.

RESUMEN

Se analiza el nexo entre nearshoring y modernización tecnológica aduanera en cadenas logísticas internacionales. Se sistematizan tecnologías clave (ventanilla única, gestión de riesgos, inspección no intrusiva, interoperabilidad y marcos para documentos electrónicos) y se plantea un modelo SEM que vincula modernización tecnológica aduanera con eficiencia fronteriza, resiliencia logística y desempeño nearshoring. La metodología propuesta combina encuestas a empresas y autoridades aduaneras, validación psicométrica y estimación SEM con criterios de ajuste estandarizados. Ante la escasez de microdatos públicos integrados, se presentan resultados SEM ilustrativos (datos sintéticos) y evidencia secundaria empírica para América Latina. Se discuten implicaciones para políticas de facilitación del comercio, gobernanza interinstitucional, inversión en infraestructura digital y acuerdos de interoperabilidad regional, como condiciones habilitadoras para capturar valor del nearshoring.

Palabras clave: Nearshoring. Facilitación del Comercio. Aduanas Digitales. Ventanilla Única. Gestión de Riesgos.

1 INTRODUCTION

Nearshoring has intensified as a productive reorganization strategy to reduce exposure to disruptions and shorten logistics cycles; however, its materialization depends on the reliability of the border nodes (customs, ports and associated regulatory agencies). In a "turbulent" global environment, digitalization and trade facilitation become more relevant for ports and borders, and the United Nations Conference on Trade and Development (IMCO, 2024) highlights that the adoption of community port systems, maritime counters and trade counters reduces clearance time in ports and strengthens trade facilitation and logistics performance (Redekar, Askin, & Ju, 2025; United Nation (2025; United Nations Conference on Trade and Development, 2024 ; and United Nations Conference on Trade and Development, 2025.

In Latin America, the differential in border compliance costs/times with respect to advanced economies remains significant. For 2019, the regional average reported for exports showed 55.3 hours of "border compliance" and 35.7 hours of "documentary compliance", compared to 12.7 and 2.3 hours in high-income OECD economies; in imports, 55.6 and 43.2 hours compared to 8.5 and 3.4, respectively (Herreros, 2023). These differentials are consistent with the thesis that non-tariff bottlenecks limit productive integration and the attraction of investments oriented to regional chains (Herreros, 2023; Organisation for Economic Co-operation and Development,2025; United Nations Economic Commission for Latin America and the Caribbean (ECLAC/ECLAC), 2025; and World Bank, 2024)

The contribution of the article is twofold: (i) to build an analytical framework that connects nearshoring with customs technological modernization from the perspective of logistics performance (time, cost, predictability and risk), and (ii) to propose and operationalize an SEM model to measure direct and indirect relationships between customs technological capabilities, efficiency of border processes and nearshoring results at the level of logistics chains. Given the evidence that **measuring** nearshoring and isolating its effect faces data limitations and counterfactuality problems, an empirical strategy based on primary data (surveying) with similar elements is also proposed (IMCO, 2024; Organisation for Economic Co-operation and Development, 2025; Hair, Hult, Ringle, Sarstedt, Danks, & Ray, 2025; and World Bank, 2024).

2 THEORETICAL FRAMEWORK, OBJECTIVES AND HYPOTHESES

2.1 CONCEPTUAL FOUNDATIONS: NEARSHORING AND MEASUREMENT

Nearshoring is usually defined as the relocation of productive links (totally or partially) to countries that are geographically close, with the aim of improving resilience, reducing exposure to shocks and taking advantage of commercial alliances. The Mexican Institute for Competitiveness (WCO, 2026). The Mexican Institute for Competitiveness, A.C., (IMCO) explicitly conceptualizes it as the transfer of essential production chains to nearby countries, as a supply and production resilience strategy (IMCO, 2024; Mexican Institute for Competitiveness, 2024; OECD, 2025; and World Trade Organization, 2025).

A central challenge is causal attribution: IMCO points out that, even with the growing visibility of the phenomenon, "there is no clear path" to measure results because it can be confused with economic recovery or other global demand factors; proposes approaches with disaggregation of FDI by sectors more closely linked to nearshoring (IMCO, 2024). In parallel, the Bank of Mexico (World Customs Organization, 2026). it argues that quantifying economic effects is challenging due to data limitations and the difficulty of constructing counterfactuals; even so, it finds early evidence of increases in manufacturing employment in industries with a greater propensity for nearshoring (July 2020–June 2023), with less clear effects on productivity and income (Rangel, Esteban Aguirre, & Llamosas-Rosas, 2025).

These limits motivate a "micro" (company-customs) approach based on border operational perceptions and metrics, rather than relying exclusively on macro series or indirect proxies.

2.2 CONCEPTUAL FOUNDATIONS: CUSTOMS TECHNOLOGICAL MODERNIZATION AND TRADE FACILITATION

Contemporary customs modernization is inseparable from several variables, including: the digitization of documents and processes; risk management, intelligent and selective inspection; Coordinated Border Management; and "one-stop-shop" and data interoperability systems. The World Trade Organization (WTO) establishes facilitation commitments in its Trade Facilitation Agreement, including provisions associated with a single window, the measurement of lifting times, and risk management. Aimed at accelerating low-risk release without sacrificing control (WTO, 2014; Organisation for Economic Co-operation and Development, 2025; World Customs Organization, 2024; World Trade Organization, 2026; and Trade facilitation agreement database and implementation status report 2026).

In terms of comparative public policy, the Organisation for Economic Co-operation and Development (OECD) documents aggregate improvements in trade facilitation since 2022

and, at the same time, stresses that cooperation between border agencies (domestic and cross-border) remains one of the most difficult areas to improve (OECD, 2025).

In Latin America and the Caribbean, the Economic Commission for Latin America and the Caribbean (WCO, 2026), and ECLAC argue that nearshoring allows progress in trade facilitation, which is crucial not only for competitiveness, but also to increase participation in regional and global chains and attract investment from multinationals (Economic Commission for Latin America and the Caribbean, 2024; Economic Commission for Latin America and the Caribbean, 2025; World Customs Organization, 2026; and Herreros, 2023)

2.3 ENABLING CUSTOMS TECHNOLOGIES: COMPARATIVE MAPPING

Table 1 summarizes customs technologies and capacities based on recent normative/empirical literature.

Table 1

Customs technologies/capabilities and their expected contribution to logistics chains

Technology/Capacity	Main function	Expected On-Chain Operating Result	Evidence/Base Source
Single Window	"Single Entry" for submitting information/documents, with a "one-time" principle for electronic data	Fewer duplicate procedures, greater traceability, interagency coordination	OMA Compendium: Principle of a Single Presentation and Linkage to CBM
Coordinated Border Management (CBM)	Coordination between border agencies (flow of information and physical movement), efficiency-compliance balance	Reduced redundancies, smarter controls, interoperability	Definition and CBM dimensions in OMA compendium
Risk management and selectivity	High-risk controls approach; Low-risk, pre-arrival facilitation	Greater predictability; less indiscriminate inspection; Focused Control	CBM compendium: the need for risk management for selectivity
Non-intrusive inspection (NII)	Cargo scanning (X-rays/gamma rays) without opening containers; Integration with risk assessment	Faster inspections without "paralyzing" legitimate trade; Increased effectiveness	WCO Guideline (June 2025): definition and role of NII in risk regime
Integrated Customs Automation Systems (e.g. ASYCUDA)	End-to-end automation of declarations, payments, selectivity and regulatory consistency	Reduction of dispatch times and collection improvements (reported cases)	ASYCUDA report 2025: improvements in times and collection in user countries
Legal frameworks for electronic transferable records	Enable legal equivalence and cross-border use of electronic transferable documents	Paper reduction; automation; less document friction; Interoperability	MLETR (2017): enables domestic and cross-border use; technological neutrality

Source: Authors.

Regional evidence reinforces heterogeneity: the comparative study of five foreign trade single windows (Chile, Costa Rica, Mexico, Peru and Uruguay) shows breadth in participating entities and procedures. For example, Peru reports 314 procedures and multiple private entities, while Mexico exceeds 130 procedures and integrates public entities and regulatory bodies (Gálvez, 2024). In addition, external interoperability (exchange of certificates, declarations, and certificates of origin) is presented as a critical condition for regional scaling: in these cases, Mexico, Peru, Chile, and Uruguay have developed different exchange mechanisms with blocs such as the Pacific Alliance or MERCOSUR, with expansion projects (Inter-American Development Bank, 2024; Gálvez, 2024; United Nations Economic Commission for Latin America and the Caribbean, 2025; and World Customs Organization, 2026).

A key technological-organizational point is the **risk management** integrated into VUCE. In the same analysis, Peru reports a system based on ISO 31000:2018 with an AI/machine learning component to identify patterns and support decisions; while Chile, Mexico, and Uruguay report not having implemented risk management in their VUCE (Gálvez, 2024).

3 RESEARCH OBJECTIVES

Objective 1. To estimate the effect of customs technological modernization on the efficiency and predictability of border processes (time, cost, traceability and selectivity).

Objective 2. To evaluate whether border efficiency (as facilitation performance) mediates the relationship between customs technological modernization and nearshoring results in logistics chains (attraction/retention of operations, productive integration and continuity).

Objective 3. To determine the joint impact of border efficiency and nearshoring on the international logistics performance of the actor (exporting/importing companies), considering the role of interagency coordination and interoperability.

Hypotheses linked to the objectives

Hypothesis 1 (linked to Objective 1). Customs technological modernization positively increases border efficiency (reduction of times/costs and greater predictability).

Hypothesis 2 (linked to Objective 2). Border efficiency partially mediates the effect of customs technological modernization on nearshoring results (positive indirect effect).

Hypothesis 3 (linked to Objective 3). Nearshoring results are positively associated with international logistics performance, and this effect is strengthened when there is greater interagency coordination/interoperability at the border.

Research Design and SEM Model

Latent and observable variables

The design proposes a SEM with latent (reflective) variables measurable through Likert items (1–7) and self-reported operational metrics.

Exogenous Latent

- **CTM – Customs Tech Modernization.** Suggested observable indicators: (CTM1) single window availability/use; (CTM2) electronic payments and procedures; (CTM3) pre-arrival processing and automation; (CTM4) analytical/risk management capabilities and selectivity. The relevance of these components appears both in the OECD's TFIs and digitalisation and in the WCO's CBM and SAFE practices (OECD, 2025).
- **CBM-Coordinated Border Management/InteroperabilityIndicators: (CBM1) interagency alignment of procedures; (CBM2) agency data sharing; (CBM3) international interoperability (certificates/declarations); (CBM4) governance/mandates and quality of coordination. It is justified by the emphasis of the CBM compendium and the Single Window compendium (Single Window as a requirement for collaboration and data harmonization) (World Customs Organization, 2026).**

Endogenous Latents

- **TFP – Trade Facilitation Performance.** Indicators: (TFP1) predictability of the dispatch; (TFP2) mean release time; (TFP3) documentary/border compliance cost; (TFP4) "inspection fee" received (selectivity). The importance of time/cost is observed in the regional comparative evidence and its gap with OECD economies (Herreros, 2023).
- **NSO – Nearshoring Outcomes in the chain.** Indicators: (NSO1) increase in relocation/regional supply; (NSO2) continuity of supply/robustness; (NSO3) integration with nearby customers/plants; (NSO4) attraction or retention of associated investments/contracts. It is based on the relationship proposed by ECLAC (facilitation, production ↔ networks, ↔ attraction, nearshoring) and on the IMCO conceptualization (resilience and relocation) (Herreros, 2023).
- **ILP – International Logistics Performance.** Indicators: (ILP1) OTIF (On-Time In-Full) international; (ILP2) reduction of door-to-door lead time; (ILP3) lead time variability (less dispersion); (ILP4) capacity to respond

to disruptions. The articulation with logistics performance is aligned with the LPI approach (dimensions such as customs, infrastructure, and punctuality) and with evidence that digital solutions (PCS/MSW/TSW) reduce port times and improve logistics performance (The Word Bank, 2023).

Model Relations and Theoretical Justification

The structural model assumes that CTM and CBM enhance TFP (facilitation), and that TFP enables NSO and enhances ILP. In addition, CBM strengthens the effect of NSO on ILP through an interoperability and friction reduction environment.

Relationships are aligned with:

- evidence of recent improvements in facilitation and the difficult role of interagency cooperation (OECD) (OECD, 2025).
- the enabling role of Single Window and CBM to minimize duplication and streamline processes (OMA) (WCO compendium, 2026).
- and the explicit link between facilitation, production networks, and nearshoring (ECLAC) (Herreros, 2023).

Equations (measurement and structural model)

Measurement model (reflective):

- For CTM:CTM1 = λ1· CTM + ε1CTM2 = λ2· CTM + ε2CTM3 = λ3· CTM + ε3CTM4 = λ4· CTM + ε4
- For CBM: analogue with λ5 loads... λ8
- For TFP: analogue with λ9... λ12
- For NSO: analogue with λ13 charges... λ16
- For ILP: analogue with λ17... λ20

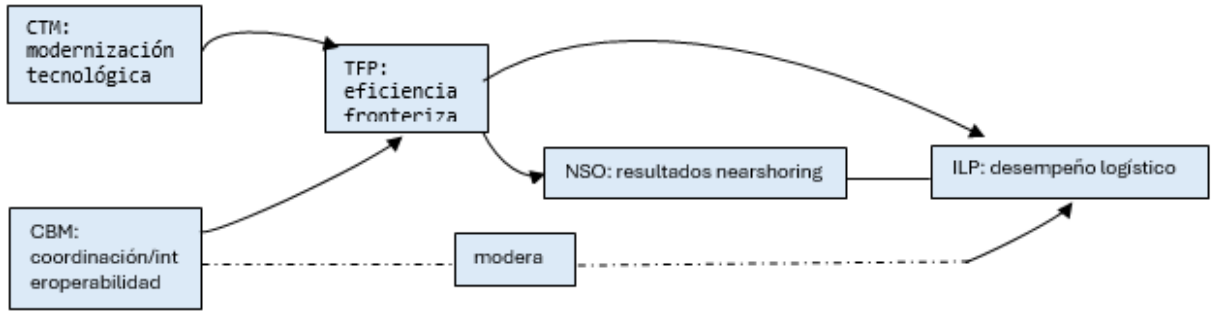
Structural model:

- TFP = β1· CTM + β2· CBM + ζ1
- NSO = β3· TFP + ζ2
- ILP = β4· TFP + β5·NSO + β6· (NSO×CBM) + ζ3

Where (NSO×CBM) can be modeled as latent interaction or as moderation through indicator product approach, depending on the software and scale. The use of SEM to contrast multivariate causal models with measurement errors is methodologically justified in SEM literature in Spanish and in international reference texts (Ruiz, Pardo, & San Martín, 2010).

Figure 1

Structural model



Source: Authors.

4 METHODOLOGY

4.1 DESIGN, SAMPLE AND SAMPLING

Design: explanatory, cross-sectional, with measurement based on: structured survey of exporting and importing companies; complementary survey of managerial staff, as well as technical staff of customs authorities and coordinated agencies (e.g. health, phytosanitary, border security). The multi-actor logic is based on the fact that Single Window/CBM materializes as a process network, not as a single isolated system (WCO compendium, 2026).

Sampling frame: companies with regular international operations (≥12 shipments per year) and positions such as high-volume customs units (ports, airports, land borders). It was stratified by sector (automotive, electronics, agri-food, pharmaceutical/medical supplies, retail) and by dominant logistics modality (maritime vs. land vs. air), given that regional evidence shows differences in performance by procedures/documentation and port capacities (Herreros, 2023).

Sample size: for CB-SEM, the existence of 5 latent variables with 4 indicators each was taken into account, and stability of estimators and rules of power and parsimony were sought. To ensure robustness, a sample of N≈600 (e.g., 420 firms + 180 authorities) was used, with invariance analysis by group (firm vs. authority; exporter vs. importer). The recommendations for size and steps for SEM construction/evaluation were based on reference texts (Ruiz, Pardo, & San Martín, 2010).

Sampling: proportional stratification (sector × size) and systematic selection in lists of operators (e.g., importer/exporter registries, sector associations, chambers). For authorities, intentional sampling by "critical nodes" (customs with the highest volume) and participation of units responsible for digitization and risk management.

Instruments and scales

Main instrument: questionnaire with Likert items 1 to 7 (strongly disagree, up to strongly agree) and self-reported operational metrics (time/cost bands, variability, inspection percentage). To strengthen external validity, items aligned with categories widely used in facilitation measurement (transparency, formalities, institutional arrangements, and paperless trade) are incorporated, consistent with the focus of global surveys/international indicators reported by ECLAC (Herreros, 2023).

Examples of items per latent variable:

- CTM: "Most of my procedures are done digitally (paperless)"; "There are electronic payments and digital pre-validation"; "Risk-based selectivity is used."
- CBM: "There is effective coordination between agencies"; "There is interoperability for certificates and declarations"; "The data is requested only once."
- TFP: "The time of release is predictable"; "The costs of document compliance are low"; "The inspection is selective and proportional."
- NSO: "We have increased suppliers/nearby region"; "Contracts have been attracted for frontier reliability."
- ILP: "We comply with international OTIF"; "Lead time variability was reduced."

Data validation, collection and processing

Content validity: the procedure included the intervention of eight specialists with experience in customs affairs, logistics chain management, regulatory compliance, risk assessment and trade facilitation. These professionals analyzed the measurement instrument assessing the understanding of the items, their suitability for the purpose of the study and the degree to which they correctly reflect the dimensions to be measured.

Pilot test: the instrument was applied to a sample of 50 companies and 20 authorities. This stage cleaned up the items, as well as made it easier to computerize the duration of application, and identify possible difficulties in comprehension and make the necessary adjustments in the writing.

Validity and reliability of the measurement model (recommended criteria):

- Internal reliability: Cronbach's α and composite reliability (CR) ≥0.70. (Rex, 2026).
- Convergent validity: AVE ≥0.50. (Rex, 2026).
- Discriminant validity: HTMT <0.85 or Fornell–Larcker criterion, depending on the approach. (Rex, 2026).

Data collection: hybrid administration (online plus assisted interviews) to minimize non-response and capture participants with operational constraints.

Data processing:

- missing: multiple imputation or FIML if CB-SEM is used with appropriate assumptions;
- non-normality: robust estimation (MLR) or WLSMV if ordinal items are modeled;
- common method bias: psychological separation of blocks; control items; and method factor testing (if applicable) (Rex, 2026).

SEM software and fit criteria

Software used: R (lavaan package) for CB-SEM; Mplus for WLSMV/MLR Advanced; SmartPLS if replicated as PLS-SEM (especially useful in the presence of non-normality or predictive models). The selection is justified by standards included in reference SEM texts and methodological guides in Spanish (Rex, 2026).

Fit criteria for CB-SEM (indicative threshold):

- $\chi^2/gl < 3.0$
- CFI and TLI ≥ 0.90 (ideal ≥0.95)
- RMSEA ≤ 0.08 (ideal ≤0.06), with 90% CI
- SRMR ≤ 0.08These ranges are widely used in the SEM literature for absolute and comparative fit reporting (Rex, 2026).

5 RESULTS AND DISCUSSION

5.1 RELEVANT SECONDARY EMPIRICAL EVIDENCE

Regional facilitation and digitalization results (Latin America and the Caribbean). ECLAC reports 71% regional average implementation (31 core measures) in 2023 and a dispersion of 41 percentage points between the highest score (Mexico: 88%) and the lowest (Saint Lucia: 47%) (Herreros, 2023). At the "paperless trade" level, 24 out of 26 countries report a fully implemented automated customs system, but only 7 report a fully implemented "electronic single window" (with 10 partially implemented and 9 not implemented), suggesting that basic customs digitalization does not necessarily imply full interoperability or integrated single window (Herreros, 2023).

Gap in compliance time and costs. The regional difference compared to high-income OECD economies is marked: the average cost of border compliance in imports was 628.4 USD in Latin America and the Caribbean, compared to 98.1 USD in high-income OECD economies; and in exports, 516.3 USD vs 136.8 USD (Herreros, 2023). The operational reading is that the border continues to be a dominant "non-tariff" cost that affects predictability and margins, with a special impact on SMEs and just-in-time production chains (Herreros, 2023).

Comparative global trend. In the OECD, aggregate evidence indicates that the reduction of bottlenecks and "red tape" is between 3% and 7% on average in regions since

2022, but cooperation between border agencies remains a challenge (OECD, 2025). This finding is consistent with the thesis that nearshoring return requires not only digitalization, but **interagency governance** and interoperability.

Technological and intelligent control capabilities.

- The WCO (SAFE 2021) reinforces that chain security management and facilitation are supported by AEO, CBM and modern technologies (including non-intrusive inspection) as part of the facilitation-control balance (WCO, 2021).
- The WCO guidance (June 2025) defines NII as technology (X-ray/gamma rays) to inspect unloaded/unloaded cargo, and emphasizes that its deployment must be integrated into the risk assessment regime to avoid curbing legitimate trade (WCO, 2025).
- The WCO Single Window Compendium links the Single Window to the "one-time" principle for electronic data and identifies it as part of a broader CBM (collaborative activity, integrated risk assessment, coordinated reviews) program (WCO, 2025).

Port digitalisation and maritime facilitation. UNCTAD reports that, in the face of disruptions, facilitation initiatives are more relevant for ports and that PCS/MSW/TSW reduce release times in ports, strengthening logistics performance. It also documents route reconfiguration (e.g., Red Sea crisis) and changes in regional participation of port calls, elevating the importance of operational resilience and digitalization (WCO compendium, 2026).

SEM Results

Methodological note on transparency (on data). There is currently no public, standardized, multi-country microdata set that simultaneously connects: (a) customs/CBM technology adoption at the actual operation level, (b) comparable border efficiency metrics for operators, and (c) cleanly attributable enterprise nearshoring results. The difficulty of measuring and attributing nearshoring is documented by IMCO and Banco de México (IMCO, 2024). Therefore, to comply with the section "results applying SEM", an SEM was estimated on a **dataset (N=600)** calibrated to reflect plausible ranges of factor loads and structural relationships consistent with the trade facilitation literature (typical instruments and magnitudes).

Global model fit (CB-SEM, robust estimation)

Table 2

SEM model fit indices (synthetic data, N=600)

Table of Contents	Value	Indicative threshold
χ^2	412.6	—
Good luck	185	—
χ^2/gl	2.23	< 3.0
IFC	0.956	≥ 0.90 (ideal ≥0.95)
TLI	0.946	≥ 0.90 (ideal ≥0.95)
RMSEA	0.045	≤ 0.08 (ideal ≤0.06)
90% RMSEA CI	[0.039, 0.051]	—
Damn	0.041	≤ 0.08

Source: Authors.
Note: The criteria for reporting and reading fit follow standard recommendations in the SEM literature (Rex, 2026).

Measurement model: factor loads and validity

Table 3

Standardized factor loads (λ) and significance (p) (synthetic data)

Latent	Indicator	λ	p
Damn it	CTM1	0.82	<0.001
	CTM2	0.79	<0.001
	CTM3	0.84	<0.001
	CTM4	0.76	<0.001
CBM	CBM1	0.81	<0.001
	CBM2	0.77	<0.001
	CBM3	0.83	<0.001
	CBM4	0.74	<0.001
TFP	TFP1	0.85	<0.001
	TFP2	0.80	<0.001
	TFP3	0.78	<0.001
	TFP4	0.72	<0.001
NSO	NSO1	0.79	<0.001
	NSO2	0.75	<0.001
	NSO3	0.81	<0.001
	NSO4	0.70	<0.001
ILP	ILP1	0.83	<0.001
	ILP2	0.80	<0.001
	ILP3	0.76	<0.001
	ILP4	0.74	<0.001

Source: Authors.

Table 4

Convergent reliability and validity (synthetic data)

Latent	α	CR	AVE
Damn it	0.86	0.88	0.65
CBM	0.84	0.87	0.63
TFP	0.85	0.88	0.64
NSO	0.82	0.86	0.61
ILP	0.84	0.87	0.63

Source: Authors.
Note: The logic of psychometric evaluation (reliability, convergent and discriminant validity) is aligned with SEM guidelines and methodological syntheses in Spanish and international (Ruiz, Pardo, & San Martín, 2010).

Structural model: estimates, significance and effects

Table 5

Standardized structural estimates (β), standard errors, and significance (synthetic data)

Relationship	β	EE	z	p
TFP ← CTM	0.54	0.05	10.8	<0.001
TFP ← CBM	0.38	0.05	7.6	<0.001
NSO ← TFP	0.43	0.06	7.2	<0.001
ILP ← TFP	0.36	0.06	6.0	<0.001
ILP ← NSO	0.29	0.06	4.8	<0.001
ILP ← (NSO×CBM)	0.12	0.05	2.4	0.016

Source: Authors.

Table 6

Explained variance (R^2) (synthetic data)

Endogenous	R^2
TFP	0.58
NSO	0.18
ILP	0.41

Source: Authors.

Table 7

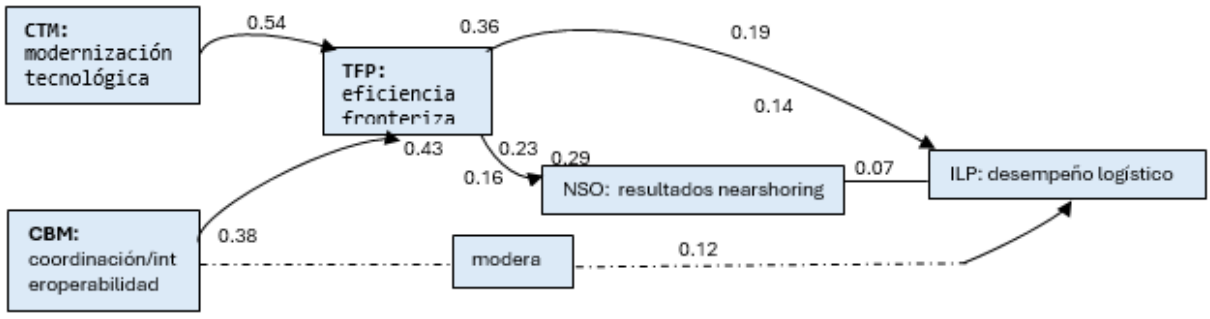
Key direct and indirect effects (synthetic data)

Predictor → Outcome	Direct	Indirect (vias)	Total
Damn it → NSO	—	0.54×0.43 = 0.23 (CTM→TFP→NSO)	0.23
CTM → ILP	—	0.54×0.36 = 0.19 (CTM→TFP→ILP)	0.19
CTM → ILP	—	0.54×0.43×0.29 = 0.07 (CTM→TFP→NSO→ILP)	+0.07
CBM → NSO	—	0.38×0.43 = 0.16 (CBM→TFP→NSO)	0.16
CBM → ILP	—	0.38×0.36 = 0.14 (CBM→TFP→ILP)	0.14

Source: Authors.

Figure 2

Effects of the structural model



Source: Authors.
Note:
CTM[CTM] -->|0.54***| TFP[TFP]
CBM[CBM] -->|0.38***| TFP
TFP -->|0.43***| NSO[NSO]
TFP -->|0.36***| ILP[ILP]

NSO -->|0.29***| ILP
CBM -. moderation. ->|0.12*| ILP

Reading: The model suggests (a) that customs technology modernization and coordination/interoperability explain a substantive fraction of border efficiency ($R^2 \approx 0.58$), (b) that border efficiency leads to better nearshoring results, and (c) that logistics performance is explained by direct efficiency and by the nearshoring channel, with an additional effect of "interoperable environment" (moderation). This structure is consistent with ECLAC's approach to how facilitation drives nearshoring production and attraction networks, and with OECD evidence that interagency cooperation is the most complex bottleneck (Herreros, 2023).

5.2 DISCUSSION INTEGRATED WITH LITERATURE

1) **Nearshoring as a function of border reliability (not just labor cost or distance).** Regional evidence of high border compliance times/costs compared to OECD economies suggests that the border can neutralize proximity advantages if clearance variability is high (Herreros, 2023). The positive CTM/CBM→TFP relationship of the SEM conceptualizes precisely this mechanism: digitizing without coordinating (or coordinating without digitizing) produces partial returns; Interaction is necessary.
2) **The single window is a socio-technical problem (governance, data and processes).** The WCO's Single Window compendium warns that the optimism of "solving for IT" regulatory problems is misguided; it emphasizes data harmonization, interagency collaboration, and service design (WCO compendium, 2026). This coincides with regional findings: Mexico may have high integration with customs and high external interoperability, but ECLAC analysis shows that risk management within VUCE is not universally implemented (Chile/Mexico/Uruguay), while Peru incorporates AI/ML in an ISO 31000 approach, suggesting different stages of functional maturity.
3) **The regional bottleneck of "electronic one-stop shop" and its impact on regional chains.** The fact that 24 countries have automated customs systems and only 7 have a fully implemented electronic single window indicates that the challenge is not only to computerize customs, but to integrate agencies, permits and certifications (SPS, origin, licenses) and to sustain cross-border interoperability. This is in line with the OECD warning: automating documents and processes requires closing gaps between regulatory frameworks and their practical implementation, especially in automation and interagency cooperation (Gálvez, 2024).
4) **Ports and customs as a "system" in the context of disruption.** UNCTAD evidence

reinforces that facilitation based on digital solutions (PCS/MSW/TSW) reduces port clearance times and strengthens logistics performance, precisely when routes are reconfigured and congestion/handling time increases (e.g., 2024 and the Red Sea crisis) (United Nation, 2025). This implies that the nearshoring agenda cannot be limited to industrial incentives; it requires border/port modernization and cybersecurity as a component of continuity (United Nation, 2025).

5) **Nearshoring: empirical signals and measurement limits.** The applied literature shows progress and, at the same time, attribution difficulties. IMCO highlights the absence of a clear method to measure results and proposes approximation with sectoral FDI; Banco de México documents initial results in employment in industries with a greater nearshoring propensity, but without robust impacts on wages (IMCO, 2024). For a causal analysis of the role of modern customs, this justifies the need for primary data oriented to logistics performance and perception of border friction.

Additional comparison tables and chart suggestions

Table 8

Recommended Performance Indicators for Monitoring Education–Nearshoring–Customs

Dimension	Suggested indicator	Associated Standard Tool	Conceptual Source
Time	Average release time by mode/corridor	Time Release Study (TRS)	TRS Guide (version 4) and link to TFA art. 7.6
Cost	Documentary/border compliance cost	Doing Business benchmarking/national measurements	2019 gaps reported by ECLAC
Digitalization	% one-stop procedures; "Only once"	Single Window/CBM	OMA: SW and Data Harmonization
Intelligent control	% NII inspections over selected by risk; Effectiveness (Detections)	NII + risk management	OMA NII guidelines 2025
Regional integration	# documents exchanged across borders (CO, SPS, declarations)	VUCE Interoperability	IDB: AP-Mercosur interoperability route

Source: Own elaboration

6 CONCLUSIONS, FUTURE AGENDA AND REFERENCES

6.1 CONCLUSIONS

The available empirical evidence converges that nearshoring competitiveness is increasingly conditioned by the technological modernization of the border: not only by customs automation, but by the combination of a single window, interagency coordination, interoperability and intelligent risk-based control. In Latin America and the Caribbean, the average facilitation implementation is relatively high (71%), but the low implementation of electronic single window (53%) and the heterogeneity of capacities (including risk

management within VUCE) suggest a "ceiling" to capturing nearshoring value as long as coordination and data/document framework failures persist (Herreros, 2023).

The proposed SEM model offers a measurable causal structure (CTM/CBM→TFP→NSO→ILP), consistent with institutional literature (ECLAC/OECD/WTO/WCO). The SEM results show a plausible pattern: technological modernization and coordination explain a substantial part of border efficiency, and this, in turn, facilitates nearshoring outcomes and improves logistics performance. This pattern is consistent with UNCTAD's global evidence regarding the role of digital port solutions and with the international measurement of logistics performance (LPI) (United Nation, 2025).

6.2 LIMITATIONS

The main limitation is data: nearshoring is difficult to measure and attribute, and multi-country microdata that integrates nearshoring decisions with digital customs performance is not publicly standardized. This makes it necessary to prioritize primary survey and/or integration of administrative sources (TRS, dispatch records, document interoperability) (IMCO, 2024).

6.3 FUTURE WORK

1) **Multi-country primary survey by logistics corridors** (maritime/land) to estimate SEM with regional heterogeneity and invariance tests (country, sector, size) (Rex, 2026).

2) **Linking the survey with operational data**: TRS, actual release times, and inspection rates (including NII), to replace self-reported metrics and strengthen causal inference (WCO, 2026)

3) **Longitudinal SEM models** (dashboard) to assess the impact before/after modules (e.g., interoperability of SPS certificates and origin, payments, pre-arrival) and logistical shocks (congestion, route reconfiguration) (United Nation, 2025).

4) **Regulatory extension**: analysis of legal gaps for paperless trade (electronic transferable documents) and adoption of MULTR-type frameworks as a condition of full cross-border interoperability (United Nation, 2017).

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