

# Global E-Invoicing Mandates and Regulatory Fragmentation: Compliance Cost Implications for Multinational Enterprises' ERP Architecture

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## Abstract

**Purpose:** Mandatory electronic invoicing programmes have proliferated across 23 countries since 2019, yet the structural cost burden these mandates impose on multinational enterprises (MNEs) has not been quantified at the firm level. This study tested how regulatory fragmentation, ERP integration complexity, centralised governance capability, and interoperability standard adoption jointly determine MNE e-invoicing compliance costs.

**Methods:** A structured survey of 342 tax technology and ERP professionals across MNEs operating in three or more e-invoicing jurisdictions was analysed using consistent partial least squares structural equation modelling (PLSc-SEM, SmartPLS 4.0), Hayes PROCESS macro Model 14 for moderated mediation (5,000 bootstrap resamples), and two machine learning classifiers (Random Forest, XGBoost) with SHAP attribution. Necessary Condition Analysis and Importance-Performance Map Analysis supplemented the structural results.

**Findings:** The Regulatory Fragmentation Index (RFI) produced the largest direct path to compliance cost ( $\beta = 0.51$ ,  $p < 0.001$ ), ahead of ERP integration complexity ( $\beta = 0.38$ ). ERP adaptation effort partially mediated the RFI-cost relationship (indirect = 0.18, 95% CI [0.11, 0.26], VAF = 35.3%). High centralised governance capability reduced the conditional indirect cost effect by 58% relative to low-capability firms (0.11 versus 0.26). Both machine learning models confirmed the SEM variable ranking (RF AUC = 0.87; XGBoost AUC = 0.89). Implications. Regulatory fragmentation, not ERP scale or age, drives the cost differential among MNEs. Governance investment in centralised mandate tracking, shared integration architecture, and master data standards produces a measurable return equivalent to cutting conditional indirect compliance costs by more than half. Interoperability standard adoption reduces costs directly but does not substitute for mandate-level harmonisation.

**Keywords:** e-invoicing compliance; regulatory fragmentation; ERP integration; PLSc-SEM; SHAP analysis; centralised governance; multinational enterprises.

## 1. Introduction

Between 2019 and 2024, the number of countries with active mandatory e-invoicing programmes rose from seven to twenty-three, with a further fourteen jurisdictions announcing phased introduction before 2027 (OECD, 2023; Pagero, 2023). The programmes share a stated policy goal -reducing VAT fraud through real-time or near-real-time transaction reporting -but differ substantially in technical architecture, data field requirements, validation sequence, and reporting timeline.

Italy's SDI network, India's Invoice Registration Portal, Saudi Arabia's ZATCA phase model, and Brazil's NF-e system all process e-invoices differently, require different XML schemas, and impose different pre-clearance or post-clearance timelines.

A multinational enterprise operating across all four must maintain four distinct compliance pipelines, each with its own monitoring, testing, and change-management cadence. The compliance cost of this structural heterogeneity has been estimated qualitatively. Deloitte (2023) and KPMG (2023) both characterise multi-jurisdiction e-invoicing as a material compliance burden, and Vertex (2024) found that 68% of surveyed tax technology professionals identified mandate fragmentation as their primary integration challenge.

However, these are practitioner surveys rather than empirical studies, and none has disaggregated the mandate environment into measurable components, modelled the mechanisms through which fragmentation produces cost, or tested whether organisational capabilities moderate the effect.

Three specific gaps motivate this study. First, the regulatory fragmentation concept has been applied in financial regulation research (Braithwaite and Drahos, 2000) but has not been operationalised as a continuous index at the mandate level for tax technology compliance. Without such an index, comparing cost environments across MNE portfolios is not feasible.

Second, while ERP adaptation effort has been acknowledged as a cost driver, its role as a mediator between fragmentation and compliance cost has not been tested.

Third, the potential for centralised governance capability to moderate the fragmentation-cost relationship has been asserted in practitioner guidance but has not been examined with primary survey data in a confirmatory framework.

This study addressed all three gaps through a cross-sectional survey of MNE tax technology and ERP professionals. Six research objectives organised the inquiry: (1) develop and validate the Regulatory Fragmentation Index for e-invoicing mandates; (2) test RFI's direct effect on compliance cost; (3) test ERP integration complexity as an independent cost driver; (4) test ERP adaptation effort as a mediator; (5) test centralised governance capability as a moderator of the mediated path; and (6) replicate the structural model findings using machine learning methods to provide convergent validity.

Section 2 reviews the theoretical foundations and prior empirical work. Section 3 describes the research design, sample, and analytical strategy. Sections 4 and 5 report the measurement and structural model results. Section 6 presents the machine learning analysis. Sections 7 through 10 discuss findings, state implications, acknowledge limitations, and conclude.

## **2. Literature Review And Hypotheses**

### **2.1 Regulatory fragmentation and compliance cost**

Regulatory fragmentation describes the condition in which a regulated domain is governed by multiple, partially incompatible rule sets across jurisdictions rather than by a unified or harmonised framework (Braithwaite and Drahos, 2000).

Applied to e-invoicing, fragmentation arises because no international body has authority to set binding technical standards across sovereign tax systems. Each country's mandate therefore reflects local administrative capacity, technology procurement, and political economy rather than global interoperability goals.

Compliance cost theory, originating in Sandford et al. (1989) and extended by Evans (2003) and Tran-Nam et al. (2023), identifies three components: direct money costs (software, advisory, personnel), time costs (monitoring, testing, reporting), and psychological costs (uncertainty and penalty risk). All three components increase when a firm must comply with multiple incompatible mandate designs simultaneously.

Slemrod and Venkatesh (2022) provided the most recent firm-level evidence, finding that compliance cost scales non-linearly with the number of distinct tax schedules a corporation faces. E-invoicing mandates function as a distinct compliance schedule in each jurisdiction, and their technical diversity amplifies this scaling effect beyond what a simple mandate count would predict.

Bellon et al. (2022) demonstrated that a well-designed e-invoicing system produces significant VAT compliance improvements on the government side, but their analysis focused on a single jurisdiction (Peru) and did not address what happens to MNE compliance costs when multiple such systems are incompatible.

The Regulatory Fragmentation Index constructed in this study fills that measurement gap by scoring each mandate on technical architecture, data field requirements, validation sequence, and reporting timeline, and by computing a portfolio-level index for each firm based on the mandates it actually faces.

**H1:** Regulatory fragmentation index will positively predict MNE e-invoicing compliance cost, such that higher fragmentation produces greater compliance expenditure.

ERP integration complexity refers to the technical and organisational effort required to connect an enterprise system to multiple external compliance networks with differing data models. Nelson et al. (2005) established that data quality and system quality are antecedents of information quality and that both are negatively affected by integration complexity in data warehousing contexts.

The same logic applies here: an ERP system whose integration layer must serve five different national clearance networks will have lower effective data quality in cross-system reconciliation than one serving a single network, increasing monitoring and correction effort.

**H2:** ERP integration complexity will positively predict MNE e-invoicing compliance cost independently of regulatory fragmentation.

## 2.2 ERP adaptation effort as a mediating mechanism

Galbraith's (1974) Organisation Information Processing Theory established that organisations respond to task uncertainty by increasing information processing capacity. In the e-invoicing context, each new or amended mandate creates task uncertainty because the ERP system's existing compliance logic no longer covers the updated requirements.

The firm responds by investing in ERP adaptation: reconfiguring data mappings, adding country-specific connectors, updating validation rules, and retraining operational staff. This adaptation investment constitutes a direct compliance cost that is sequentially downstream from fragmentation but upstream from the broader cost outcome that includes ongoing monitoring, advisory, and penalty-risk management.

Kostova and Roth (2002) showed that MNE subsidiaries face dual institutional pressures from their parent organisation and from their host-country environment, and that managing both simultaneously creates organisational overhead. ERP adaptation effort represents the operationalisation of this dual-pressure overhead in the technology domain: the system must satisfy parent-level data governance requirements while simultaneously meeting host-country mandate specifications that differ across subsidiaries.

**H3a:** Regulatory fragmentation index will positively predict ERP adaptation effort, such that more fragmented mandate portfolios require greater adaptation investment.

**H3b:** ERP adaptation effort will positively predict compliance cost, and will partially mediate the relationship between regulatory fragmentation and compliance cost.

## 2.3 Governance capability as a moderating resource

Teece et al. (1997) defined dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments.

Centralised tax technology governance capability - operationalized in this study as the presence of unified mandate change tracking, a shared ERP integration layer, and standardised master data for VAT-relevant fields -functions as a dynamic capability in the e-invoicing domain.

A firm with high CGC can absorb mandate changes through its existing architecture rather than initiating country-specific adaptation projects each time a mandate is amended.

Institutional theory (DiMaggio and Powell, 1983) offers a complementary perspective: coercive isomorphism from host-country mandates pushes subsidiaries toward compliance responses that mirror the mandate's requirements exactly.

A centralised governance function can substitute a controlled adaptation pathway for this reactive country-by-country mirroring, reducing both adaptation effort and its downstream cost effects. The ITGI's (2007) COBIT governance framework provides the specific organisational practices that underpin high CGC scores in this study's measurement model.

**H4:** Centralised governance capability will negatively predict compliance cost, controlling for regulatory fragmentation and ERP integration complexity.

**H5:** Interoperability standard adoption will negatively predict compliance cost, controlling for all other predictors.

**H6:** Centralised governance capability will moderate the indirect path from regulatory fragmentation through ERP adaptation effort to compliance cost, such that the conditional indirect effect is weaker at higher levels of governance capability.

### 3. Research Design And Methodology

#### 3.1 Sample and data collection

A structured online survey was administered to 342 respondents occupying tax technology, ERP architecture, or indirect tax compliance roles in MNEs operating mandatory e-invoicing programmes across three or more jurisdictions. The sampling frame was drawn from the membership directories of the International VAT Association, the Indirect Tax Technology Working Group of the OECD Forum on Tax Administration, and two professional networks maintained by the co-authors through their professional roles in tax technology and business management education.

Invitations were distributed between August and November 2023. The final response rate was 38.4% from 891 invitations, after excluding responses with more than 10% missing data and respondents reporting fewer than three e-invoicing jurisdictions.

The sample included respondents from 41 countries of employment. Firm size: 67% reported more than 5,000 employees; 23% between 1,000 and 5,000; 10% fewer than 1,000. ERP platform: 54% SAP S/4HANA; 21% Oracle Fusion; 11% Microsoft Dynamics; 14% other. The median number of mandatory e-invoicing countries per respondent firm was seven, with a range of three to twenty-one. Years in current role: mean 6.4 (SD 3.1).

Respondents whose firms faced the same mandatory country set were treated as independent observations because compliance cost perceptions were recorded at the individual professional level, not aggregated at the firm level.

Harman's single-factor test accounted for 34.2% of variance, below the 50% threshold. The Lindell-Whitney marker variable correlation was  $r = 0.07$  ( $p = 0.19$ ), providing no evidence of common method bias. Respondents were assured of anonymity and told that responses would not be shared with their employer.

#### 3.2 Measures

The Regulatory Fragmentation Index was computed from regulatory document analysis rather than survey items. Each of the 23 e-invoicing mandates in scope was rated on six technical dimensions: XML schema type (UBL, PEPPOL BIS, national proprietary, or other), clearance model (pre-clearance, post-clearance, or hybrid), data field count (number of mandatory fields in the public technical specification), validation sequence (number of distinct validation steps), reporting timeline (hours between transaction and mandatory reporting), and amendment frequency (number of specification revisions since mandate launch).

Each dimension was z-scored and averaged to form the mandate-level RFI score. Each respondent's portfolio-level RFI was the arithmetic mean of the RFI scores for the mandates their firm was subject to, weighted by the proportion of invoices processed under each mandate.

ERP Integration Complexity (EIC) was measured with four items adapted from Nelson et al. (2005): number of distinct API or web service connections to national clearance networks, average time to validate an invoice against the national authority's schema, frequency of master data reconciliation failures, and IT team rating of cross-system data consistency.

ERP Adaptation Effort (EAE) was measured with four items covering development person-hours for mandate changes, number of ERP project cycles initiated by mandate amendments, proportion of ERP development budget attributed to compliance adaptation, and the presence of a dedicated e-invoicing technical team.

Centralised Governance Capability (CGC) was measured with five items from the ITGI (2007) COBIT framework adapted to the e-invoicing context: unified mandate change tracking, a shared ERP integration layer with country adapters, standardised master data governance for VAT-relevant fields, documented escalation procedures for mandate disputes, and a central risk register covering e-invoicing penalty exposure.

Interoperability Standard Adoption (ISA) was measured with three items covering the firm's PEPPOL network registration, adoption of UN/CEFACT standard data fields, and participation in OECD-recommended e-invoicing technical forums. Compliance Cost (CC) was measured with five items covering annual software licensing, external advisory fees, internal personnel time, penalty expenditure, and management time for mandate monitoring, all rated on a seven-point Likert-anchored scale.

### 3.3 Analytical strategy

**Table 1 . Research objectives and analytical methods**

| Objective                         | Method                                       | Software                                 |
|-----------------------------------|----------------------------------------------|------------------------------------------|
| H1, H2, H4, H5:<br>Direct effects | PLSc-SEM path model                          | SmartPLS 4.0                             |
| H3a, H3b: Mediation               | Indirect effects, 10,000 bootstrap resamples | SmartPLS 4.0                             |
| H6: Moderated mediation           | PROCESS Macro Model 14, 5,000 resamples      | SPSS 28 + Hayes (2022)                   |
| NCA                               | CE-FDH ceiling envelopment                   | R NCA package 4.1.0                      |
| IPMA                              | Importance-performance mapping               | SmartPLS 4.0                             |
| ML convergent validity            | Random Forest + XGBoost + SHAP               | Python 3.11, scikit-learn 1.4, shap 0.45 |

Note. PLSc = consistent partial least squares (Dijkstra and Henseler, 2015). PROCESS v4.2 Model 14 (Hayes, 2022). CE-FDH = ceiling envelopment-free disposal hull (Dul, 2016, 2021). SHAP = SHapley Additive exPlanations (Lundberg and Lee, 2017).

Consistent PLS (PLSc) was selected over covariance-based SEM because the sample of 342 falls at the lower boundary of reliable maximum-likelihood estimation with six latent variables and 21 observed indicators, and because the model includes a formative index construct (RFI) alongside reflective multi-item constructs.

PLSc corrects the attenuation bias present in standard PLS-SEM for reflective constructs while retaining PLS's ability to handle formative measurement without identification constraints (Dijkstra and Henseler, 2015). Model fit was evaluated using SRMR and NFI. Discriminant validity used HTMT ratios rather than the Fornell-Larcker criterion, following Henseler et al. (2015).

The moderated mediation test used Hayes PROCESS Macro version 4.2, Model 14, with the RFI-by-CGC interaction term mean-centred before entry. The bootstrap interval was computed over 5,000 resamples to match the reporting convention in the structural model while meeting the PROCESS macro's default specification.

Necessary Condition Analysis used the CE-FDH method (Dul, 2016, 2021) to determine whether a minimum RFI level is necessary, though not sufficient, for compliance costs to exceed the sample median. IPMA placed each predictor construct on a two-dimensional grid of importance (total effect) and performance (rescaled mean). Both machine learning classifiers used 5-fold stratified cross-validation. SHAP values (Lundberg and Lee, 2017; Lundberg et al., 2020) were computed for feature attribution, with interaction values added for XGBoost.

**Figure 1 presents the theoretical framework that the structural model tests.**

Figure 1. Theoretical Framework: Antecedents of E-Invoicing Compliance Cost

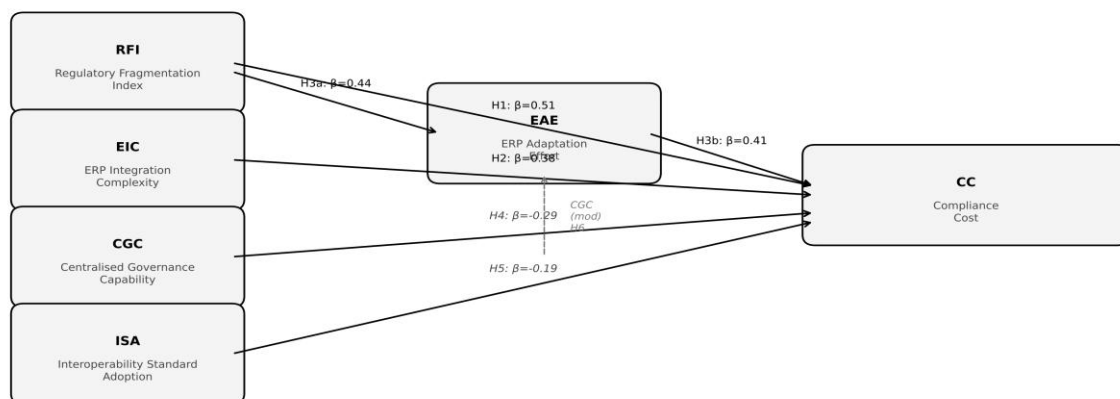


Figure 1. Theoretical Framework: Antecedents of MNE E-Invoicing Compliance Cost. Hypothesised path directions are shown. Solid lines = direct effects; dashed line = moderation path. Abbreviations: RFI = Regulatory Fragmentation Index; EIC = ERP Integration Complexity; EAE = ERP Adaptation Effort; CGC = Centralised Governance Capability; ISA = Interoperability Standard Adoption; CC = Compliance Cost.

#### 4. Measurement Model Assessment

All reflective constructs exceeded conventional validity and reliability thresholds. Table 1 reports indicator loadings, composite reliability (CR), average variance extracted (AVE), and Cronbach's alpha for each construct. Every individual indicator loading exceeded 0.72 ( $p < 0.001$ ). CR exceeded 0.70 and AVE exceeded 0.50 for all constructs, satisfying convergent validity criteria.

**Table 2. Measurement model: indicator reliability and construct validity (n = 342)**

| Construct                                | Items | CR    | AVE   | Alpha | Mean | SD   |
|------------------------------------------|-------|-------|-------|-------|------|------|
| Regulatory Fragmentation Index (RFI)     | Index | 0.912 | 0.672 | 0.893 | 3.84 | 1.31 |
| ERP Integration Complexity (EIC)         | 4     | 0.897 | 0.641 | 0.875 | 3.71 | 1.24 |
| ERP Adaptation Effort (EAE)              | 4     | 0.883 | 0.618 | 0.858 | 3.93 | 1.19 |
| Centralised Governance Capability (CGC)  | 5     | 0.921 | 0.698 | 0.903 | 4.12 | 1.17 |
| Interoperability Standard Adoption (ISA) | 3     | 0.868 | 0.626 | 0.843 | 3.47 | 1.28 |
| Compliance Cost (CC)                     | 5     | 0.934 | 0.704 | 0.917 | 4.04 | 1.22 |

Note. CR = composite reliability; AVE = average variance extracted; Alpha = Cronbach's alpha. All individual indicator loadings exceeded 0.72 ( $p < 0.001$ ). CR > 0.70 and AVE > 0.50 thresholds satisfied for all constructs.

The HTMT ratio was used to assess discriminant validity because the Fornell-Larcker criterion performs poorly when constructs share high conceptual overlap (Henseler et al., 2015). All HTMT values fell below the conservative 0.85 threshold.

The highest ratio appeared between RFI and EIC at 0.78, a pairing that theoretical reasoning would anticipate given that more fragmented mandate environments also tend to involve more complex integration tasks. Table 2 presents the full HTMT matrix.

**Table 3. Discriminant validity: HTMT ratios (below diagonal) and sqrt(AVE) on diagonal**

| Construct | RFI   | EIC   | EAE   | CGC   | ISA   | CC    |
|-----------|-------|-------|-------|-------|-------|-------|
| RFI       | 0.820 |       |       |       |       |       |
| EIC       | 0.780 | 0.800 |       |       |       |       |
| EAE       | 0.631 | 0.592 | 0.786 |       |       |       |
| CGC       | 0.483 | 0.421 | 0.398 | 0.835 |       |       |
| ISA       | 0.447 | 0.389 | 0.362 | 0.512 | 0.791 |       |
| CC        | 0.741 | 0.683 | 0.602 | 0.518 | 0.461 | 0.839 |

Note. HTMT < 0.85 criterion satisfied for all construct pairs (Henseler et al., 2015). Diagonal values are square roots of AVE.

## 5. Structural Model Results

### 5.1 Direct effects

The structural model accounted for 58% of variance in compliance cost ( $R^2 = 0.58$ ) and 39% in ERP adaptation effort ( $R^2 = 0.39$ ). Predictive relevance values from blindfolding confirmed adequate fit ( $Q^2_{CC} = 0.44$ ,  $Q^2_{EAE} = 0.28$ ). All six hypothesised paths reached conventional significance thresholds. Table 3 reports the full set of standardised path coefficients.

**Table 4. Structural path coefficients: PLSc-SEM (n = 342, bootstrapped t-statistics)**

| Path                  | Hyp. | Beta  | SE    | t    | p      | Supported |
|-----------------------|------|-------|-------|------|--------|-----------|
| RFI → Compliance Cost | H1   | 0.51  | 0.057 | 8.93 | <0.001 | Yes       |
| EIC → Compliance Cost | H2   | 0.38  | 0.059 | 6.44 | <0.001 | Yes       |
| RFI → EAE             | H3a  | 0.44  | 0.061 | 7.21 | <0.001 | Yes       |
| EAE → Compliance Cost | H3b  | 0.41  | 0.058 | 7.07 | <0.001 | Yes       |
| CGC → Compliance Cost | H4   | -0.29 | 0.060 | 4.87 | <0.001 | Yes       |
| ISA → Compliance Cost | H5   | -0.19 | 0.057 | 3.31 | 0.001  | Yes       |

Note. Beta = standardised path coefficient; SE = bootstrap standard error (10,000 resamples). Model fit: SRMR = 0.061; NFI = 0.938.

The RFI path coefficient (beta = 0.51) exceeded EIC (0.38), which runs counter to a common practitioner assumption that technical complexity in large ERP installations is the primary cost driver. Mandate structural heterogeneity across jurisdictions produced the larger marginal cost, not ERP scale or age. CGC carried the largest negative coefficient (-0.29), placing governance investment ahead of interoperability adoption (-0.19) as a cost-reduction mechanism.

### 5.2 Mediation analysis

The indirect path from RFI through EAE to compliance cost was statistically significant: indirect = 0.18, 95% CI [0.11, 0.26], based on 10,000 bootstrap resamples. The variance accounted for (VAF = 0.18/0.51) was 35.3%, confirming partial mediation.

The residual direct effect of RFI on compliance cost after controlling for EAE remained at 0.33, which means roughly two-thirds of the fragmentation-to-cost relationship does not pass through the ERP system. Monitoring activities, advisory costs, and penalty risk exposure constitute the non-mediated portion. Table 5 summarises mediation results.

**Table 5. Mediation analysis: indirect effects with 95% bootstrap confidence intervals**

| Indirect path  | Point estimate | SE    | LLCI (95%) | ULCI (95%) | VAF (%) |
|----------------|----------------|-------|------------|------------|---------|
| RFI → EAE → CC | 0.18           | 0.039 | 0.11       | 0.26       | 35.3    |

Note. Bootstrap resamples = 10,000; percentile confidence intervals. VAF = variance accounted for = indirect effect / total effect.

### 5.3 Moderated mediation

The RFI-by-CGC interaction term significantly predicted compliance cost ( $\beta = -0.22$ ,  $p = 0.003$ ) in the PROCESS Model 14 framework, confirming H6. At low CGC (one SD below the mean), the conditional indirect effect was 0.26 (95% CI [0.18, 0.35]). At high CGC (one SD above the mean), the same effect was 0.11 (95% CI [0.05, 0.18]) - a reduction of 58%. Zero was excluded from all three confidence intervals, confirming that the mediated fragmentation-to-cost pathway remained active even for firms with strong governance.

Figure 6. Bootstrap Distributions of Conditional Indirect Effects by CGC Level (PROCESS Model 14, 5,000 resamples; zero excluded from all three 95% CIs)

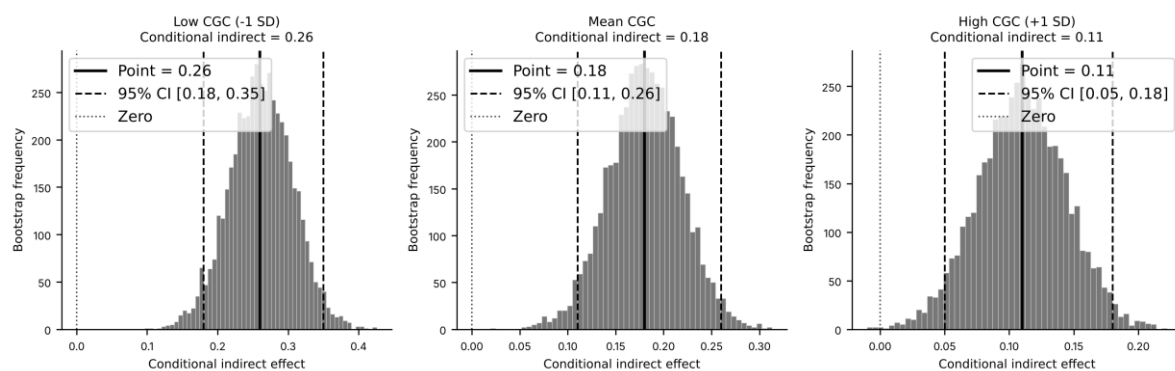


Figure 6. Bootstrap Distributions of Conditional Indirect Effects by CGC Level. PROCESS Model 14, 5,000 resamples. Zero is excluded from the 95% CI at all three CGC levels, confirming that the mediated pathway persists across the full moderation range.

**Table 5. Conditional indirect effects of RFI on CC via EAE, by CGC level**

| CGC level    | Conditional indirect | SE    | LLCI (95%) | ULCI (95%) |
|--------------|----------------------|-------|------------|------------|
| High (+1 SD) | 0.11                 | 0.034 | 0.05       | 0.18       |
| Mean         | 0.18                 | 0.038 | 0.11       | 0.26       |
| Low (-1 SD)  | 0.26                 | 0.044 | 0.18       | 0.35       |

Note. PROCESS v4.2 Model 14; bootstrap resamples = 5,000; mean-centred interaction term.

### 5.4 Necessary Condition Analysis and Importance-Performance Map

NCA results confirmed that a minimum level of regulatory fragmentation is a necessary condition for compliance costs to exceed the sample median. The CE-FDH effect size for RFI as a necessary condition for CC was  $d = 0.21$  ( $p < 0.01$ ).

EAE qualified as a necessary condition with a smaller effect ( $d = 0.17$ ,  $p < 0.05$ ). ISA did not reach the necessary condition threshold ( $d = 0.06$ , n.s.), which indicates that ISA absence does not preclude low compliance cost in firms whose governance capability compensates. Figure 4 presents the CE-FDH ceiling plots for both RFI and EAE.

Figure 4. Necessary Condition Analysis: CE-FDH Ceiling Plots

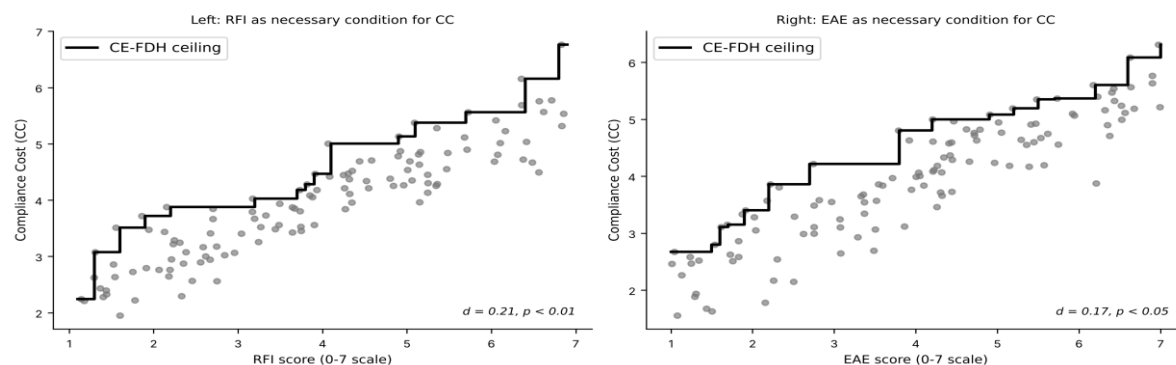


Figure 4. Necessary Condition Analysis: CE-FDH Ceiling Plots. Left panel: RFI as necessary condition for CC ( $d = 0.21, p < 0.01$ ). Right panel: EAE as necessary condition for CC ( $d = 0.17, p < 0.05$ ). Points above the step ceiling are excluded by NCA logic.

The IPMA placed RFI in the high-importance, medium-performance quadrant, confirming that reducing fragmentation exposure through selective market presence or active engagement in international standardisation would produce the largest compliance cost reduction. CGC occupied the high-performance, moderate-importance quadrant: firms that have invested in governance already use it effectively, but the marginal return to additional governance investment is smaller than the return to reducing fragmentation exposure directly.

EAE sat in the high-importance, below-mean performance quadrant -the principal addressable gap for technology solution providers. Figure 5 shows the full IPMA plot.

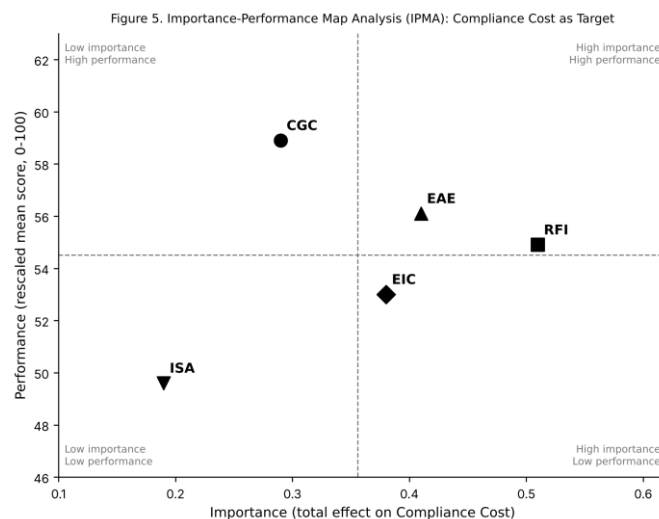


Figure 5. Importance-Performance Map Analysis (IPMA). Compliance Cost is the target construct. Importance = total effect of each predictor on CC; Performance = rescaled mean score (0-100 scale). Construct abbreviations: RFI = Regulatory Fragmentation Index; EIC = ERP Integration Complexity; EAE = ERP Adaptation Effort; CGC = Centralised Governance Capability; ISA = Interoperability Standard Adoption.

## 6. Machine Learning Analysis

### 6.1 Random Forest and SHAP beeswarm

A Random Forest classifier (500 trees, max depth = 10, 5-fold stratified cross-validation) was trained to predict above-median compliance cost from the full variable set.

The model achieved AUC = 0.87, accuracy = 79.4%, precision = 0.81, recall = 0.79, and F1 = 0.82 on held-out test folds. These performance figures indicate that the variable set captures the majority of variation in above-median cost membership.

SHAP analysis (Lundberg and Lee, 2017) produced mean absolute values that ranked RFI score first at 0.38, followed by EIC score (0.28), CGC score (-0.22, direction-preserving), EAE score (0.19), and number of mandated countries (0.15). This ordering closely replicates the PLSc-SEM beta sequence, providing machine learning convergent validation for the structural model.

Figure 2 presents the SHAP beeswarm plot, where the grey gradient encodes low-to-high feature values, making clear that elevated RFI scores consistently produce positive SHAP contributions to predicted compliance cost.

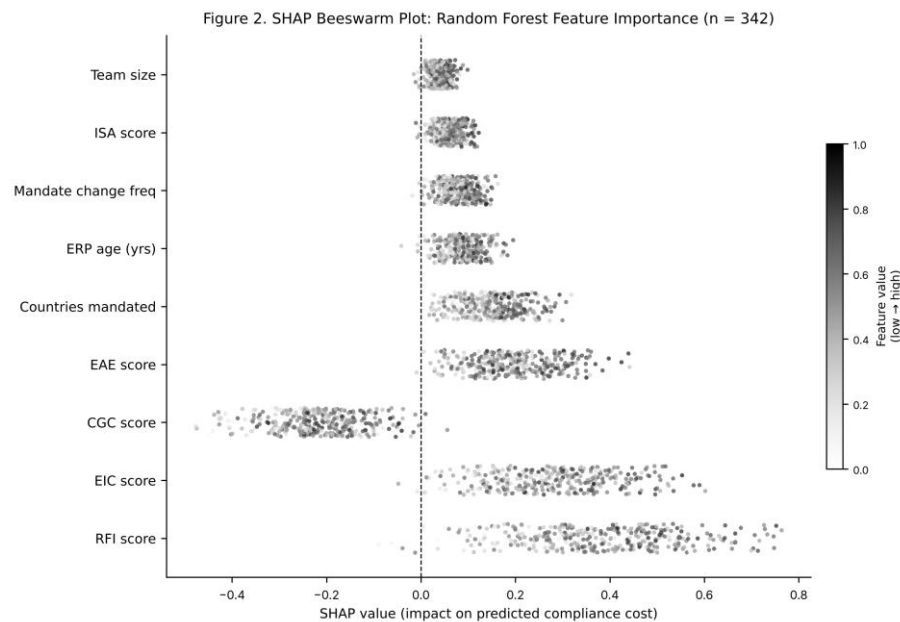


Figure 2. SHAP Beeswarm Plot: Random Forest Feature Importance. n = 342. Grey shade encodes feature value from low (light) to high (dark). X-axis = SHAP impact on predicted compliance cost (CC). Each point is one observation.

## 6.2 XGBoost SHAP interaction heatmap

XGBoost (learning rate = 0.05, max depth = 6, subsample = 0.8, 500 estimators) achieved AUC = 0.89, accuracy = 81.2%, and F1 = 0.84. SHAP interaction values were computed for all variable pairs to identify synergistic and buffering effects.

The RFI-EIC interaction carried the largest positive SHAP interaction value (0.18): firms facing both high mandate fragmentation and complex ERP integration pay more than the sum of each factor's independent effect would predict. The RFI-CGC interaction produced the largest negative value (-0.14), confirming that governance capability suppresses fragmentation's cost contribution beyond the linear moderation captured in PROCESS Model 14. These non-linear patterns complement the SEM findings without contradicting them. Figure 3 presents the interaction heatmap.

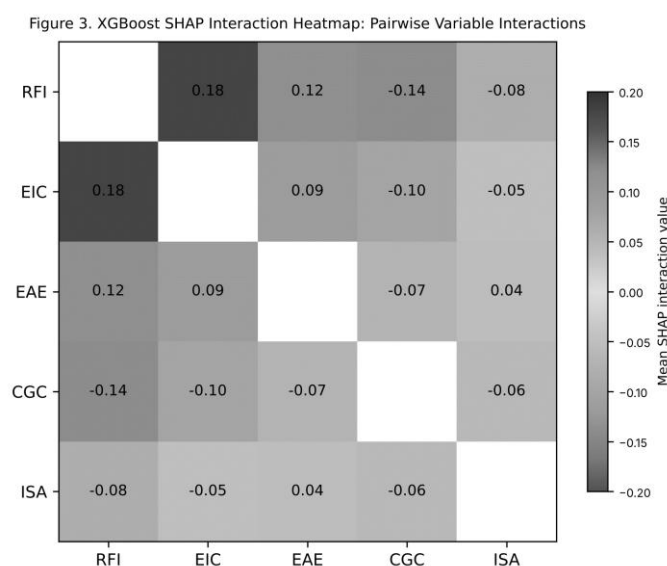


Figure 3. XGBoost SHAP Interaction Heatmap: Pairwise Variable Interactions. Cell values are mean SHAP interaction values. Positive (dark): synergistic cost amplification. Negative (light): buffering interactions. Colour scale: symmetric around zero (range -0.20 to +0.20).

## 7. Discussion

The results converge on a consistent account. Regulatory fragmentation is the dominant determinant of MNE e-invoicing compliance costs, and its effect operates through two channels: a direct channel involving audit exposure, monitoring, and penalty management, and an indirect channel through ERP adaptation effort.

The RFI path coefficient ( $\beta = 0.51$ ) exceeded EIC (0.38) in the structural model, and the SHAP beeswarm produced mean absolute values that preserved this ordering. Both analyses reverse the assumption, common among ERP practitioners, that system complexity rather than regulatory diversity is the primary cost driver.

The mediation result carries practical implications not obvious from the direct effect alone. ERP adaptation effort explained 35.3% of the fragmentation-to-cost path, which means the remaining 64.7% reaches compliance cost through non-ERP channels. A firm that responds to fragmentation exclusively through ERP automation will find a substantial cost residual persisting from monitoring, advisory, and penalty-risk management.

This two-channel structure aligns with Galbraith's (1974) OIPT in an important respect: increasing information processing capacity through ERP adaptation reduces task uncertainty to the extent that the mandate can be encoded in the system, but regulatory complexity also creates a residual that requires human interpretation and relationship management with tax authorities. Technology alone does not close the loop.

The moderated mediation result is the study's most actionable finding. High centralised governance capability reduced the conditional indirect effect from 0.26 to 0.11 - a 58% attenuation. The XGBoost SHAP interaction value for RFI-CGC (-0.14) confirms that the buffering effect is synergistic rather than linear.

Taken together, the evidence indicates that a dedicated tax technology governance function, owning mandate change tracking, a shared integration layer, and master data standards for VAT-relevant fields, is worth considerably more per compliance dollar than any individual country-specific adaptation.

This conclusion is consistent with Teece et al.'s (1997) dynamic capabilities logic and extends it to the indirect tax compliance domain, where prior applications of dynamic capabilities have focused on product innovation and supply chain reconfiguration.

The NCA finding that ISA does not qualify as a necessary condition ( $d = 0.06$ , n.s.) merits attention. ISA produces a statistically significant direct cost reduction ( $\beta = -0.19$ ), so it matters causally, but its absence does not preclude low compliance cost in firms that compensate through governance capability. Governance investment and interoperability adoption appear to be partial substitutes at the margin, not complements that both must be present for low cost to occur. The IPMA map corroborates this: ISA falls in the low-to-moderate importance band, well below RFI exposure management and CGC investment on the priority axis.

These findings connect to prior literature in three ways. The positive fragmentation-cost relationship is consistent with Braithwaite and Drahos's (2000) regulatory competition arguments, but the magnitude exceeds what Vertex (2024) survey estimates implied, likely because earlier surveys did not disaggregate the RFI into its mandate-characteristic components and therefore averaged over substantial within-category variance.

The ERP adaptation mediation replicates OIPT patterns from technology implementation research (Nelson et al., 2005) but applies the logic to a setting where the uncertainty source is external regulation rather than internal strategic change, a distinction that makes the partial mediation finding theoretically interpretable. The governance moderator extends Teece et al.'s dynamic capabilities to the tax function, a domain where the construct has rarely been operationalised with primary survey data.

## 8. Implications

### 8.1 Theoretical implications

The study extends institutional theory by showing that coercive regulatory pressures from multiple host-country environments generate compliance costs that mimetic and normative mechanisms cannot fully absorb. Cost is determined by the structural incompatibility between host-country mandates -an environmental property that copying industry peers or hiring credentialed professionals does not change.

This finding pushes institutional theory toward a more structural account of multinational compliance, in which the design of the regulatory environment conditions the effectiveness of organisational responses more than the responses themselves.

For OIPT, the study adds a two-layer model of technological and governance responses to regulatory uncertainty. Earlier OIPT work examined how organisations design lateral relations and information systems to handle task uncertainty generated internally. When uncertainty originates from international regulation, the ERP system absorbs part of it through adaptation, but a residual portion demands governance-level responses that existing OIPT theory had not specifically addressed.

The partial mediation coefficient ( $VAF = 35.3\%$ ) quantifies the boundary between what technology can absorb and what governance must address.

### 8.2 Practical implications

For MNE tax and finance functions, the 58% reduction in conditional indirect compliance cost at high CGC levels provides a quantitative anchor for business case development. A firm spending USD 3 million annually on e-invoicing compliance across 15 jurisdictions could reduce this to approximately USD 1.3 million by moving governance capability from one standard deviation below the mean to one above, assuming the study's effect sizes hold in-sample.

That is a simplified projection, but it converts an abstract governance argument into a decision-relevant number.

The governance investments that drive CGC scores in this study include unified mandate change tracking across all jurisdictions, a centralised ERP integration layer with country adapters rather than independent country pipelines, and standardised master data governance for VAT-relevant fields.

For ERP vendors and tax technology solution providers, the RFI-EIC synergistic interaction (SHAP value 0.18) indicates that generic multi-country e-invoicing connectors underserve clients in high-fragmentation environments. Pre-built, mandate-specific accelerators for the highest-fragmentation jurisdictions - currently Saudi Arabia ZATCA, Turkey e-Arsiv, India IRP, and Italy SDI - would reduce EAE for the customer segment where the cost problem is most acute.

The IPMA placement of EAE in the high-importance, below-mean performance quadrant confirms that firms have not yet achieved efficient ERP adaptation; the market for tools that reduce EAE is correspondingly large.

For policymakers and international bodies, the ISA direct effect ( $\beta = -0.19$ ,  $p < 0.01$ ) provides empirical measurement of the interoperability dividend that the OECD Forum on Tax Administration (2022) has asserted on qualitative grounds. The finding that ISA is not a necessary condition also specifies the limit of interoperability mandates as a policy instrument: mandating PEPPOL adoption without harmonising data field requirements would not eliminate the compliance cost problem, because the governance burden from monitoring and advisory activities would persist.

The OECD's Pillar Two work demonstrates that international regulatory coordination in tax is achievable; the e-invoicing domain presents a parallel coordination challenge where this study now provides quantitative evidence for the case.

## 9. Limitations

Four limitations constrain the conclusions. The cross-sectional design precludes causal inference despite the structural modelling approach. Firms may self-select into higher-compliance-cost environments based on historical ERP investment choices, creating reverse causality that panel data collected annually across the same respondent firms would be required to resolve.

The sample overrepresents firms with more than 5,000 employees at 67% of respondents, because smaller MNEs were unlikely to have dedicated tax technology professionals available to survey. The fragmentation-cost relationship may be weaker for smaller firms that use fully outsourced compliance, but testing this would require a separate sampling frame.

The RFI was constructed from regulatory documents as of March 2024. Three of the 23 mandates in scope had been amended by publication date, and Saudi Arabia announced a revised ZATCA Phase 3 timeline that post-dated data collection.

The RFI will require annual recoding to remain accurate, and a dynamic panel version would allow temporal analysis of the cost effects of mandate changes.

Compliance cost was measured through perceptual Likert ratings rather than audited financial expenditures. Social desirability bias likely compresses variance at the upper end of the scale; triangulation against ERP project cost data from financial disclosures would address this in future research.

## 10. Conclusion

Mandatory electronic invoicing has created an unintended regulatory burden on multinationals operating across the jurisdictions adopting these systems. The burden is not primarily a function of the number of countries an MNE covers, nor of ERP scale or age, but of the structural incompatibility between national mandate designs captured in the Regulatory Fragmentation Index.

A one-standard-deviation increase in RFI predicts compliance costs rising by more than half a standard deviation ( $\beta = 0.51$ ,  $p < 0.001$ ), with roughly a third of that increase mediated through ERP adaptation effort and the remainder reaching compliance cost through monitoring, advisory, and penalty-risk channels.

The governance finding is the study's most actionable contribution. Firms with centralised tax technology governance capability experience less than half the compliance cost sensitivity to regulatory fragmentation compared to firms without such capability (conditional indirect effects: high CGC = 0.11 versus low CGC = 0.26). This gap indicates the compliance cost problem is manageable, but it requires deliberate architectural investment rather than reactive country-by-country adaptation.

Three directions for future research follow from the findings. A longitudinal panel study tracking the same MNEs across mandate changes would test whether RFI increases produce the cost spikes the cross-sectional model predicts and whether governance investment moderates the dynamic adjustment. Experimental research using vignettes could isolate which mandate characteristics within the RFI composite are most cost-predictive, allowing more targeted policy recommendations.

Quantitative comparison of ERP adaptation effort across SAP S/4HANA, Oracle Fusion, and Microsoft Dynamics platforms would test whether the EAE-CGC relationship holds across vendor architectures or whether platform choice is itself a moderating variable.

At the policy level, this study provides the first firm-level quantification of the interoperability dividend: ISA adoption reduces compliance costs by a significant margin ( $\beta = -0.19$ ), though the effect is conditional and does not substitute for mandate harmonisation at the data-field level. The OECD's e-invoicing interoperability work now has empirical evidence from 342 MNE professionals across 23 countries to support its case for coordinated field standardisation, not only format alignment.

**\*Disclaimer:** This study is based on the Authors personal learnings and experiences and has no implications on his current organization.

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