

DETERMINANTS OF E-LOGISTICS ADOPTION IN THAI NGUYEN PROVINCE: EVIDENCE FROM ENTERPRISE-LEVEL ANALYSIS

Thi Phuong Hong Bui

(Faculty of Industrial Economics, Thai Nguyen University of Technology, Vietnam)

ABSTRACT: A highly advanced electronic logistics (E-Logistics) ecosystem is a critical driver for fostering the digital economy, optimizing global supply chains, and enhancing regional macroeconomic competitiveness. This study investigates the key determinants influencing the adoption and integration of E-Logistics systems among enterprises operating in Thai Nguyen province - a rapidly industrializing and digitizing economic hub in northern Vietnam. Drawing on a structured survey of 312 enterprises operating across the manufacturing, trade, and logistics sectors, the research empirically evaluates the impacts of six core factor groups: telecommunications and digital infrastructure, administrative and regulatory frameworks, digital human capital quality, financial accessibility for technological investments, firm technological readiness, and local government support policies. Utilizing quantitative econometric methods, including Exploratory Factor Analysis (EFA) and Multiple Linear Regression (MLR), the study measures the relative structural importance of each determinant in shaping firms' e-logistics implementation. The empirical results demonstrate that telecommunications infrastructure and digital human capital are the primary drivers of adoption. Based on these findings, the paper offers practical, high-level policy recommendations for provincial authorities to accelerate logistics digitalization and move up the global value chain.

KEYWORDS - E-Logistics, Thai Nguyen Province, Digital Infrastructure, Digital Human Capital, Supply Chain Optimization, Econometric Analysis, Regional Competitiveness

I. INTRODUCTION

In the contemporary global economy, the quality, speed, and cost-efficiency of logistics systems have become central pillars of enterprise performance, investment attraction, and sustainable economic growth. In developing and transition economies such as Vietnam, logistics costs remain disproportionately high, often consuming between 16% and 20% of national GDP. This inefficiency acts as a structural tax on domestic productivity and international trade. Transitioning from legacy, paper-based traditional logistics to electronic logistics (E-Logistics)-defined as the end-to-end digital integration of Warehouse Management Systems (WMS), Transportation Management Systems (TMS), real-time Internet of Things (IoT) tracking, Enterprise Resource Planning (ERP), and Big Data analytics-presents a critical mechanism to reduce transaction costs, minimize supply chain disruptions, and catalyze innovation (Nguyen, 2013; Nguyen et al., 2025).

While central macroeconomic frameworks and national digital transformation mandates are established by the central government, the operational execution, enforcement, and localized infrastructure provisions rest heavily upon provincial authorities. Consequently, significant sub-national variations persist regarding digital readiness, public service efficiency, and localized institutional support for private enterprises. To understand these sub-national dynamics, researchers frequently look at broader indicators such as the Provincial Competitiveness Index (PCI). However, general business environment indicators cannot fully dissect the highly specialized technical, financial, and regulatory constraints encountered by firms seeking to integrate complex digital supply

chain technologies. This current paper extends that analytical paradigm by shifting from a generic evaluation of the business climate to a deeply specialized, empirical investigation into the determinants of E-Logistics adoption.

Thai Nguyen province, situated in the strategic northern midlands and mountainous region of Vietnam, offers an ideal empirical landscape for this investigation. Over the past two decades, the province has undergone a dramatic structural transformation from an agrarian economy to a major manufacturing powerhouse. Leveraging its geographical proximity to Hanoi and key maritime export corridors, Thai Nguyen has successfully attracted massive Foreign Direct Investment (FDI) inflows, spearheaded by multinational high-tech conglomerates such as Samsung Electronics Vietnam Thainguyen (SEVT). The presence of these advanced electronic manufacturing clusters has generated massive export capacities and fostered a sprawling network of domestic component suppliers. This hyper-industrialized landscape requires an agile, digitized logistics infrastructure capable of supporting just-in-time (JIT) production schedules and global market integration.

Despite these industrial advancements, the local logistics ecosystem faces acute developmental bottlenecks. Local enterprises—particularly small and medium-sized enterprises (SMEs)—frequently encounter substantial hurdles, including localized telecommunications deficits, shortages of workers with combined logistics and IT proficiencies, high capital barriers for proprietary software acquisition, and an underlying institutional framework that is still adjusting to digital commerce. These frictions prevent domestic firms from integrating into global value chains, leaving them vulnerable to lower-cost international competitors.

Existing literature on digital transformation in Vietnam heavily skews toward aggregate national data or comparative studies focused entirely on primary economic centers like Hanoi and Ho Chi Minh City. Rigorous, firm-level empirical studies that dissect the microfoundations of digital logistics adoption in industrial satellite provinces like Thai Nguyen remain noticeably absent. This study addresses this critical gap by executing a comprehensive, enterprise-level quantitative inquiry. Utilizing primary data from a structured survey of 312 diverse firms, we isolate and quantify the impacts of six fundamental factor groups adapted from the Technology-Organization-Environment (TOE) framework: (1) telecommunications and digital infrastructure, (2) administrative and electronic regulatory procedures, (3) digital human capital quality, (4) access to finance for technological investments, (5) firm technological readiness, and (6) local government digital support policies.

By applying robust statistical techniques, including scale purification, exploratory factor analysis, and multiple linear regression, this paper provides threefold academic and practical contributions. First, it contributes fresh empirical data to the literature on technological adoption in transition economies, capturing the real-world operational challenges of firms in a booming industrial corridor. Second, it synthesizes these insights through an integrated theoretical lens, bridging Transaction Cost Economics (TCE) with the TOE framework. Third, it provides actionable, highly specific policy recommendations for provincial policymakers and industry stakeholders aiming to modernize the local logistics infrastructure and enhance Thai Nguyen's long-term regional competitiveness.

II. LITERATURE REVIEW

The adoption of E-Logistics is not merely an internal corporate decision but a multi-dimensional process governed by technical, organizational, and exogenous institutional dynamics. To map these interactions, this study constructs an integrated framework derived from the Technology-Organization-Environment (TOE) model (Tornatzky & Fleischer, 1990), supplemented by Transaction Cost Economics (North, 2012; Williamson, 1985). This section reviews the theoretical underpinnings and empirical literature across the six core determinants analyzed in this study.

In digitalized supply chains, infrastructure acts as the foundational highway over which data flows. Within Transaction Cost Economics (TCE), superior digital infrastructure reduces information asymmetry and curtails search and information costs (North, 2012; Williamson, 1985). According to the World Bank (2023), high-speed broadband internet, reliable cloud computing capabilities, and continuous power grids are structural prerequisites for running automated tracking, real-time fleet management, and cloud-based Electronic Data Interchanges (EDI). Tran and Le (2022) demonstrated that in emerging economies like Vietnam, localized infrastructure disparities heavily distort firm productivity. In modern manufacturing zones, a drop in network connectivity translates directly into supply chain friction, delayed shipments, and capital inefficiencies. Thus, the

availability of advanced telecommunications infrastructure is hypothesized to have a direct, positive effect on a firm's capacity to adopt E-Logistics.

The speed of E-Logistics must be matched by the speed of regulatory clearance. Institutional economics posits that the predictability, transparency, and simplicity of administrative mechanisms dictate market efficiency (North, 2012). For logistics operators, this manifests in electronic customs platforms (e.g., the VNACCS/VCIS system in Vietnam), digital tax filings, and cross-border e-commerce regulatory frameworks. Long, bureaucratic delays and paper-based oversight impose substantial transaction costs on businesses. Empirical research utilizing the Provincial Competitiveness Index (PCI) indicates that streamlined administrative processing directly lowers informal costs and boosts firm satisfaction (VCCI & USAID, 2024). Le and Nguyen (2024) observed that provinces enforcing business-friendly, digitalized administrative platforms show accelerated rates of technology adoption within their logistics and private sectors.

The operationalization of E-Logistics technologies demands a workforce possessing hybrid competencies across logistics management and information technology. Gary Becker's Human Capital Theory (1993) emphasizes that targeted investments in specialized training and education drive marginal worker productivity, which in turn enhances firm performance. In developing economies, a profound digital skills mismatch often introduces significant barriers to technology implementation. Reports indicate that while basic literacy is high, formal vocational and advanced engineering skills tailored to digital automated systems remain scarce in certain northern provinces (Ministry of Industry and Trade [MoIT], 2023). Nguyen and Pham (2021) concluded that firms operating in clusters with strong linkages to technical universities exhibit higher innovation capacity and superior operational growth rates.

The deployment of enterprise-grade E-Logistics systems (such as customized ERP or high-end WMS platforms) requires substantial upfront capital outlays. Access to affordable external financing remains a primary developmental constraint for SMEs in emerging markets (World Bank, 2018). The Pecking Order Theory (Myers & Majluf, 1984) suggests that while firms prefer internal financing, they must seek external debt for substantial technological overhauls. In Vietnam's financial market, commercial banks are often hesitant to extend unsecured loans for intangible assets like software licenses, demanding fixed physical collateral instead. Evangelista et al. (2012) and Tran and Le (2022) verified that logistics firms with access to structured formal credit and specialized financing options exhibit substantially higher rates of technological upgrading and process innovation.

Technological readiness captures a firm's internal absorptive capacity—its ability to recognize the value of new digital information, assimilate it, and apply it to commercial ends. Under the organizational dimension of the TOE framework (Tornatzky & Fleischer, 1990), a firm's existing IT maturity, hardware inventory, and management commitment dictate its technological trajectory. Small, legacy firms often exhibit low technological readiness due to rigid corporate cultures, fear of operational disruption, and an inability to restructure traditional workflows. In an empirical review of Vietnamese logistics enterprises, Nguyen and Nguyen (2021) found that internal organizational readiness and digital maturity strongly correlate with successful digital transformation, particularly within export-oriented manufacturing networks.

Exogenous institutional support can act as a powerful catalyst to offset market failures associated with early-stage technology adoption. Michael Porter's (1990) Diamond Model underscores the role of government policy in creating a stimulating environment for firm upgrading and industry-wide innovation. At the provincial level, this support materializes as technology transfer subsidies, localized digital transformation masterplans, specialized training grants, and the establishment of dedicated industrial zones. Evangelista et al. (2012) discovered that targeted small-provider promotional programs significantly amplify the technology growth trajectory of local firms, provided these public policies are executed with transparency, administrative capacity, and minimal bureaucratic friction.

III. RESEARCH METHODOLOGY

Sampling and Data Collection

To ensure empirical rigor, this study utilizes a quantitative, cross-sectional research design. The targeted population comprises enterprises operating within Thai Nguyen province that rely heavily on logistics networks, specifically spanning the manufacturing, retail trade/e-commerce, and specialized third-party logistics (3PL) sectors.

The sampling frame was constructed utilizing corporate registries from the Thai Nguyen Department of Planning and Investment. A stratified random sampling technique was applied to guarantee that the final dataset reflected a balanced distribution of firm sizes (SMEs versus large corporations) and ownership models. To determine the appropriate sample size, Slovin's formula was used with an acceptable margin of error set at 5% and a 95% confidence level, yielding a minimum required sample size of approximately 300 firms. To account for non-response bias and incomplete records, 340 structured questionnaires were physically and electronically distributed to corporate executives (CEOs, CIOs, Logistics Directors, or IT Heads). Data collection took place between March and May 2025. After discarding 28 incomplete or invalid submissions, a final sample of 312 valid responses was retained for econometric modeling, representing a highly acceptable response rate of 91.8%.

Variable Operationalization and Measurement Scales

The survey instrument was developed by adapting validated constructs from international empirical literature (Nguyen, 2013; Nguyen et al., 2025) and tailoring them to the socio-economic conditions of Vietnam. The questionnaire was partitioned into three distinct blocks:

Demographic profiles: Sectoral classification, employment size, operational age, and capital ownership structure.

Determinants evaluation: Assessment of the six independent latent variables, measured using multiple observed indicators on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Dependent variable: The composite level of E-Logistics adoption intensity and perceived efficiency within the firm.

Econometric Specification

To test the hypothesized relationships and calculate the relative impact weights of each determinant, a Multiple Linear Regression (MLR) model was constructed. The ordinary least squares (OLS) regression equation is modeled as follows:

$$Y_i = \beta_0 + \beta_1 \text{INFRA}_i + \beta_2 \text{ADMIN}_i + \beta_3 \text{HR}_i + \beta_4 \text{FIN}_i + \beta_5 \text{TECH}_i + \beta_6 \text{POLICY}_i + \varepsilon_i$$

Where Y is the Intensity of E-Logistics adoption, β_0 is the intercept term, β_1 to β_6 are the standardized partial regression coefficients, and ε_i represents the stochastic error term. The dataset was screened for econometric violations, including multicollinearity via Variance Inflation Factors (VIF) and residual autocorrelation using the Durbin-Watson statistic.

IV. RESULTS AND FINDINGS

Descriptive Demographic Profile of the Sample

The demographic distribution of the 312 surveyed enterprises confirms a broad representation of Thai Nguyen's industrial landscape:

Sectoral Matrix: Manufacturing firms dominate the sample at 56.1%. Trade and e-commerce firms account for 28.5%, while specialized 3PL and transport service providers comprise 15.4%.

Firm Size Stratification: Small and Medium-sized Enterprises (SMEs) with fewer than 100 employees constitute 64.4% of the sample, while Large Enterprises make up the remaining 35.6%.

Capital Ownership Structure: Private domestic enterprises form the largest segment at 68.3%. Foreign-Invested Enterprises (FIEs) represent 21.8%, and State-Owned Enterprises (SOEs) make up 9.9%.

Operational Longevity: A majority (70.5%) of the firms have been operating for over 5 years.

Scale Reliability and Exploratory Factor Analysis (EFA)

Scale internal consistency was evaluated using Cronbach's Alpha coefficients. All six independent constructs exceeded the conventional reliability threshold of 0.70, demonstrating high internal cohesion:

Table 1. Results of Cronbach's Alpha test

Variables	Cronbach's Alpha
Telecommunications Infrastructure (INFRA)	0.864
Administrative Procedures (ADMIN)	0.881
Digital Human Capital (HR)	0.832
Access to Finance (FIN)	0.793
Technological Readiness (TECH)	0.804
Government Support Policies (POLICY)	0.798

Exploratory Factor Analysis (EFA) was performed using Principal Component Analysis with Varimax rotation. The Kaiser-Meyer-Olkin (KMO) measure reached 0.842, and Bartlett's Test of Sphericity was highly significant ($p < 0.001$), confirming suitability for factorization. Six distinct latent components emerged with eigenvalues greater than 1.0, cumulatively explaining 73.1% of the total variance.

Multiple Linear Regression Modeling

The purified factor scores were entered into a multiple linear regression model using SPSS 26.0 software. The aggregate model statistics are summarized below:

Table 2. Econometric Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	F-Statistic (p-value)	Durbin-Watson
0.870	0.757	0.751	0.241	159.41 ($p < 0.001$)	1.916

The Adjusted R^2 value of 0.751 indicates that approximately 75.1% of the structural variance in E-Logistics adoption intensity among the surveyed enterprises is successfully explained by the six independent determinants. The Durbin-Watson statistic of 1.916 proves that the regression residuals are free from autocorrelation.

Table 3. OLS Regression Coefficients and Multicollinearity Diagnostics

Independent Variables	Standardized β	t-statistic	p-value	VIF
(Constant)	-	7.263	0.000	-
Telecommunications Infrastructure (INFRA)	0.331	6.872	0.000	1.352
Digital Human Capital (HR)	0.298	6.144	0.000	1.287
Technological Readiness (TECH)	0.212	4.619	0.000	1.244
Access to Finance (FIN)	0.185	3.987	0.000	1.336
Administrative Procedures (ADMIN)	0.142	3.011	0.003	1.298
Government Support Policies (POLICY)	0.127	2.541	0.012	1.219

All VIF values range between 1.219 and 1.352, well below the conservative threshold of 5.0, confirming that the independent variables are free from multicollinearity distortions. The empirical results provide strong statistical evidence regarding the distinct roles that macro, organizational, and institutional factors play in driving E-Logistics adoption across Thai Nguyen province.

As indicated by the standardized beta coefficient ($\beta = 0.331$, $p < 0.001$), telecommunications and digital infrastructure exerts the single largest positive effect on E-Logistics adoption. This finding aligns with the location-specific advantages identified in Dunning's Eclectic Paradigm (1980) and modern digital supply chain literature (World Bank, 2023). For logistics-intensive firms—especially those operating within high-tech manufacturing corridors—stable fiber-optic networks and extensive 5G network grids are foundational requirements for running automated systems. Without continuous high-bandwidth internet connectivity, advanced tracking systems, cloud-hosted WMS platforms, and algorithmic fleet dispatches cannot function.

Digital human capital emerges as the second most powerful determinant within the regression model ($\beta = 0.298$, $p < 0.001$). This strongly confirms Gary Becker's Human Capital Theory (1993), highlighting that

advanced software architectures are only as effective as the personnel operating them. The statistical significance of this variable underscores a major structural constraint within Thai Nguyen province. Many firms report that while their operators are capable of executing traditional warehousing tasks, they lack the technical capability to interpret big data analytics, manage complex ERP configurations, or resolve system integrations, a baseline reality noted in emerging logistics assessments (MoIT, 2023).

Internal technological readiness displays a significant positive relationship with E-Logistics integration ($\beta = 0.212$, $p < 0.001$). This demonstrates that technology adoption is highly dependent on a firm's internal absorptive capacity (Ngo, 2024). Firms that already possess baseline digital architectures, up-to-date hardware, and forward-thinking corporate leadership exhibit a much higher willingness to adopt advanced logistics technologies.

Access to finance exhibits a positive and statistically significant coefficient ($\beta = 0.185$, $p < 0.001$). In accordance with the Pecking Order Theory (Myers & Majluf, 1984), external capital injections are essential when firms attempt major technological overhauls that exceed internal cash reserves. The positive β value shows that firms capable of securing flexible, unsecured commercial bank loans or specialized digital transformation grants implement E-Logistics systems at a significantly faster rate, mirroring broader logistics real credit findings (Nguyen et al., 2025).

Both administrative procedures ($\beta = 0.142$, $p = 0.003$) and government support policies ($\beta = 0.127$, $p = 0.012$) display positive, statistically significant coefficients. These results indicate that institutional efficiency and targeted state intervention provide important support for digital supply chain evolution. Streamlined administrative steps, particularly regarding e-customs and paperless transit licensing, lower transaction costs and encourage firms to invest in electronic data interchanges (EDI) (Tran et al., 2026).

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

The empirical findings of this study confirm that accelerating E-Logistics adoption across Thai Nguyen province requires a comprehensive approach addressing telecommunications infrastructure, digital literacy, financial access, and institutional efficiency. The following policy interventions are proposed:

Firstly, given that infrastructure stands out as the most critical determinant, Thai Nguyen must prioritize the expansion of high-speed telecommunications networks beyond premium industrial zones. Provincial authorities should incentivize telecom providers to achieve comprehensive 5G coverage across rural and suburban commercial zones, in line with modern connectivity benchmarks (World Bank, 2023). Furthermore, the province should invest in the development of centralized public data infrastructure and smart Inland Container Depots (ICDs) along major transit corridors.

Secondly, to resolve the acute shortage of digitally literate logistics workers, the Thai Nguyen provincial government should design a formal collaborative framework linking local industry with academia. Institutions such as Thai Nguyen University and its member colleges should introduce specialized degrees and short-term professional certifications in Digital Supply Chain Management, Logistics Analytics, and Smart Warehouse Engineering, matching contemporary human capital growth models.

Thirdly, to alleviate financial constraints, provincial authorities should establish a dedicated Provincial Digital Transformation Credit Guarantee Fund. By partnering with commercial banks, this fund can share credit risk, allowing financial institutions to extend low-interest loans based on technological viability and cash-flow metrics rather than requiring fixed physical assets as collateral, echoing microfoundations discussed by Tran and Le (2022).

Fourthly, local authorities must continue simplifying administrative processes to ensure that digital government utilities match the real-time operational speeds of electronic logistics. The Thai Nguyen Department of Customs and Department of Transport should integrate their platforms into a singular, paperless clearance window, reducing bureaucratic friction and maximizing policy engagement across the local business ecosystem (Tran et al., 2026; VCCI & USAID, 2024).

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