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Unlocking digital trade in Southeast Asia: The roles of infrastructure and regulation

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Abstract

Digital trade is reshaping global commerce, yet the way infrastructure and regulation interact to drive outcomes in Southeast Asia remains poorly understood. We address that gap by combining a new composite index of digital infrastructure with international measures of regulatory openness: the OECD Services Trade Restrictiveness Index, the UN E-Government Development Index, and the E-Participation Index. Using panel data for nine ASEAN economies from 2010 to 2022 and fixed-effects regression models, we examine five outcomes: ICT goods exports and imports, digitally deliverable services exports and imports, and trade openness. The results challenge conventional assumptions. Infrastructure on its own does not reliably predict performance when rules and macroeconomic fundamentals are considered. Instead, institutions, particularly regulatory restrictiveness and participatory governance, emerge as decisive. This finding advances institutional theory in the digital trade domain and offers evidence that predictable, open, and inclusive rules are more powerful than infrastructure alone in shaping regional competitiveness.

Keywords

- digital trade
- ICT goods
- digitally deliverable services
- trade openness
- ASEAN
- regulatory restrictiveness
- institutional theory

JEL codes: F14, F15, L86, O33, O57.

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Introduction

What counts as trade today is no longer confined to containers stacked on cargo ships or goods passing through customs checkpoints. Increasingly, it takes place through invisible flows of data moving across fibre-optic cables, cloud servers, and digital platforms, with orders, payments, and deliveries occurring in real time. In Southeast Asia, this transformation is especially striking. While a Singaporean design firm can sell its services to a client in Paris before lunch, firms in Cambodia still face basic hurdles in transferring large files abroad. These contrasts shape who benefits from the digital economy and who risks being left behind (OECD, 2023; Suranto et al., 2025).

Digital participation depends on two kinds of capacity. One is tangible: broadband coverage, affordable access, reliable electricity, and logistics that keep e-commerce moving (Berisha-Shaqiri, 2014; Thompson & Garbacz, 2011). The other is institutional: rules for data flows, market entry, licensing, and the treatment of digital services (Ferracane & van der Marel, 2021). When the pipes and the rulebook align, firms connect to global value chains; when they do not, opportunity shrinks (Gao & Chen, 2024; González & Ferencz, 2018).

The relationship between these two kinds of capacity is not linear. Strong networks without enabled regulation leave firms connected yet constrained. Open rules without adequate networks create theoretical access with limited practical use (González & Sorescu, 2021). Evidence that isolates this joint effect for Southeast Asia remains thin, since many studies treat infrastructure and regulation separately or generalise from global samples that blur regional dynamics (OECD, 2023; Zhang et al., 2025). Which matters more for actual trade outcomes in the region: better pipes or better rules?

This study answers that question empirically. It brings together a composite index of digital infrastructure built with principal component analysis and a set of regulatory indicators that capture the policy environment: the OECD Services Trade Restrictiveness Index (STRI) for computer services and telecommunications, the UN E-Government Development Index (EGDI), and the E-Participation Index (EPI) (González et al., 2023; OECD, 2023). The analysis covers nine Southeast Asian economies from 2010 to 2022 and estimates fixed effects panel regressions for five dependent variables that mirror the scope of the paper: ICT goods exports (ICTe), ICT goods imports (ICTi), digitally deliverable services exports (DDSEp), digitally deliverable services imports (DDSIp), and trade openness (OPN).

The contribution is twofold. Firstly, it places infrastructure readiness and regulatory openness in a single empirical frame suited to the region's policy and capacity diversity. Secondly, it shows where the leverage lies. Regulation emerges as the main bottleneck for digital trade, while infrastructure on its own does not reliably predict outcomes once macroeconomic conditions are

considered. For aggregate openness, income and prices dominate; for digital trade niches, rules carry more weight (González et al., 2023; OECD, 2023; Rahman & Rahman, 2022). The implication for policy is practical: to sequence reforms in such a way that regulatory openness moves with, not after, investment in connectivity.

The paper is organised as follows: Section 1 combines a review of the relevant literature with a brief contextual overview of digital trade development in Southeast Asia, which helps situate the empirical analysis. It sets out the conceptual links between infrastructure, regulation, and trade performance. Section 2 describes the data and empirical design, including the construction of the infrastructure index, and the use of STRI, EGDI, and EPI. Section 3 reports results for ICT goods, digitally deliverable services, and overall openness. Section 4 discusses the findings in light of current research and policy debates. The final section offers implications and outlines the next steps for the region.

1. Literature review and institutional context

1.1. Digital trade and services integration in ASEAN

Digital trade has shifted from a side issue to a core feature of global commerce. The OECD (2023) defines it as trade in goods and services that are digitally ordered, digitally delivered, or both. This reach spans e-commerce, software and platform services, digitally enabled logistics, and professional

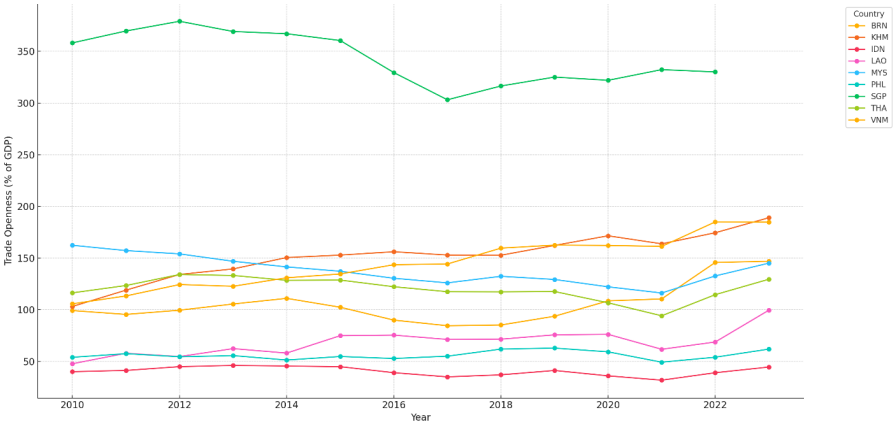

Figure 1. Trade openness in Southeast Asian countries, measured as total trade in goods and services as a percentage of GDP, 2010–2022

Source: (UNCTAD, 2025).

services. In this frame, digital trade alters how value is created, transferred, and captured rather than simply speeding up existing channels (González & Ferencz, 2018).

The growth in ASEAN is rapid and uneven. Countries that embed digital capabilities into trade systems show stronger exports, deeper value-chain participation, and greater resilience to shocks (Arora et al., 2022; Gao & Chen, 2024). Moreover, gaps in infrastructure, rules and skills risk widening the distance between the leaders and late movers.

Trade openness is commonly used in the literature as a first proxy for integration into global markets and digital readiness. Higher trade-to-GDP ratios are typically associated with stronger international linkages and greater incentives to invest in both digital infrastructure and governance (Ferracane & van der Marel, 2021). As noted in the literature and descriptive evidence, ASEAN displays wide variation, with economies such as Singapore and Brunei Darussalam exhibiting significantly higher levels of trade openness and record ratios well above 150%; Indonesia and the Philippines show more moderate levels given their large domestic markets; Vietnam and Thailand sit between these poles. Figure 1 reports total trade as a share of GDP for 2010–2022 and shows persistent structural divides with gradual improvement among mid-tier performers.

Services are the other pillar. They have grown fastest worldwide, and ASEAN follows that path. Economies that scale digitally deliverable services (DDS) gain resilience because these flows rely less on physical transport routes (Rahman & Rahman, 2022). In Southeast Asia, existing studies and descriptive data indicate uneven development across countries, with more advanced economies

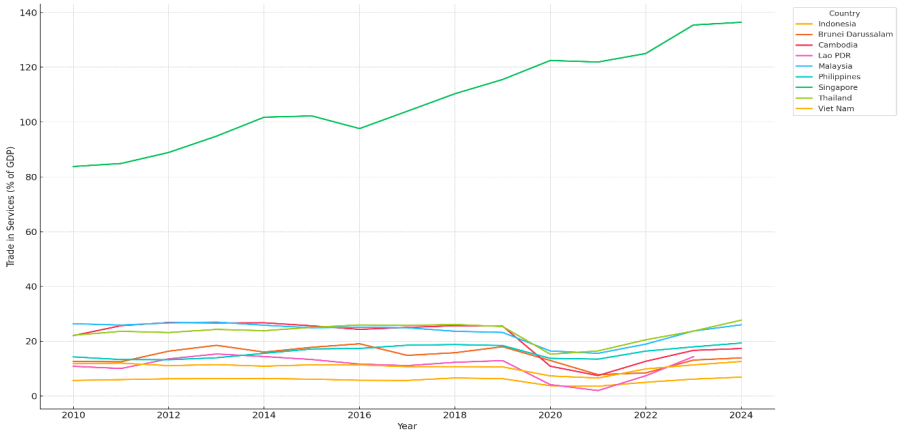

Figure 2. Trade in services as a share of GDP in Southeast Asian economies, 2010–2024

Source: (World Bank, 2025).

achieving higher levels of services integration, while others are hampered by their infrastructure, regulatory conditions, and skills gaps. Singapore leads on services intensity; Thailand, Malaysia, and the Philippines have gained ground through targeted infrastructure and reform (OECD, 2023). Figure 2 presents services trade as a share of GDP for 2010–2024 and shows divergence between leaders and others, with clear upward trends for several mid-ranked states.

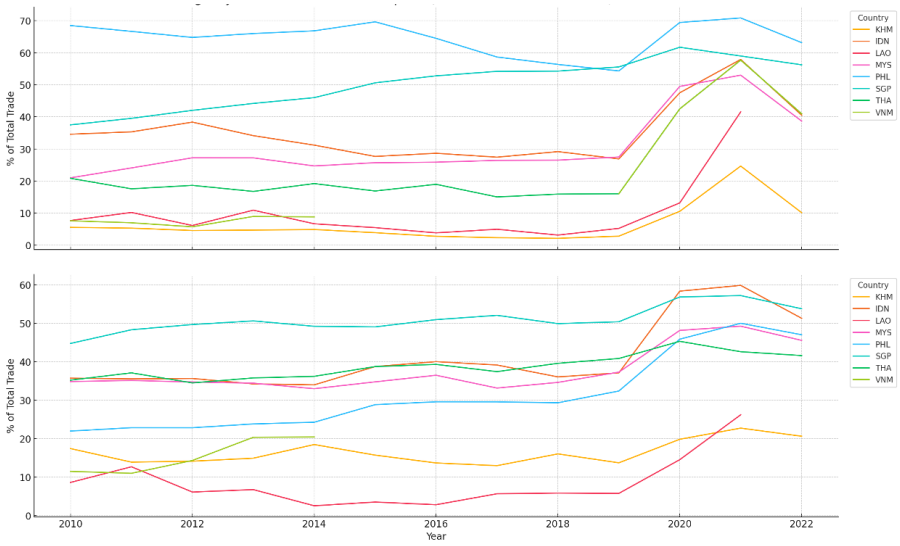

Figure 3. Digitally deliverable services exports and imports as a percentage of total trade in services in selected Southeast Asian countries, 2010–2022

Source: (UNCTAD, 2025).

The DDS share within services provides a sharper view of digital integration. High shares imply strong technology sectors, flexible rules, and skilled labour. Singapore and Malaysia exceed 50%; Cambodia and Lao PDR remain below 10% (OECD, 2023). Figure 3 provides an illustrative overview of DDS exports and imports as a share of total services trade, drawing on UNCTAD data. The patterns shown are consistent with the literature emphasising the role of digital readiness and institutional quality in shaping services trade outcomes.

1.2. Infrastructure, regulation, and institutional perspectives

ICT goods still anchor the region's digital economy. Exports and imports of computers, telecommunications equipment, and components reveal

both production capacity and reliance on global value chains. Evidence links ICT penetration to productivity gains that strengthen external competitiveness once adoption crosses key thresholds (Thompson & Garbacz, 2011). Industry 4.0 shifts in robotics, data, and automation reshape manufacturing geography, enhancing the role of ICT hardware in regional trade (Strange & Zucchella, 2017).

The ASEAN pattern is mixed: Singapore and Malaysia act as hubs for production and re-export; Vietnam has expanded its electronics assembly sector yet still imports high-value parts; Cambodia and Lao PDR remain largely import-reliant. These asymmetries justify modelling ICT goods exports (*ICTe*) and imports (*ICTi*) separately. They also clarify why both macro conditions and rules matter: income and prices shape demand and costs, and regulatory settings determine entry, standards, and data handling that govern participation in technology-intensive trade.

1.3. Digital infrastructure and the institutional environment

Digital infrastructure provides the base on which services and goods move. It includes broadband penetration, reliable electricity, secure data storage, cybersecurity, and the skills needed to operate and innovate (Berisha-Shaqiri, 2014). Threshold effects matter: once broadband crosses a certain level, productivity and trade tend to accelerate (Thompson & Garbacz, 2011). Composite measures often outperform single indicators because they combine physical assets with elements of capacity and capability (González & Sorescu, 2021).

Coverage remains uneven across ASEAN. Singapore has a near-universal high-speed access and substantial data-centre capacity; Malaysia and Thailand have expanded rapidly; Cambodia, Lao PDR, and Myanmar, however, still face bottlenecks that constrain the scale of digitally delivered services and hamper ICT integration.

Rules shape whether infrastructure translates into competitiveness. The OECD Services Trade Restrictiveness Index (STRI) captures barriers in data localisation, cross-border transfers, licensing, and foreign equity. Higher STRI scores correlate with weaker outcomes in digitally intensive services, even where infrastructure is strong (Ferracane & van der Marel, 2021). Lower barriers are associated with faster DDS growth, particularly in middle-income economies with improving networks (Zhang et al., 2025).

Regulatory regimes diverge across the region. Singapore follows liberal settings backed by bilateral and regional frameworks; Indonesia and Vietnam apply tighter rules that prioritise sovereignty and security; Malaysia and the Philippines have liberalised selectively yet retain targeted restrictions.

Digital infrastructure also helps narrow the first-level digital divide, which concerns access, or the ability of individuals and businesses to connect to the internet and use basic digital services (Livingstone & Helsper, 2007). After countries clear basic access thresholds, skills, usage patterns, and outcomes become more important for trade-related gains. EGDI and EPI capture parts of this shift by reflecting the quality of digital government and the extent of digital participation, which relate closely to the second- and third-level divides, such as digital literacy, effective use, and meaningful engagement with online platforms (Robinson et al., 2015; Yang & Zhang, 2023). This distinction helps explain why the standalone contribution of infrastructure can shrink once governance and participation factors enter the model.

Institutional theory helps interpret these patterns. Institutions shape costs and uncertainty by structuring interaction (North, 1990). Scott's (Scott, 1995) framework distinguishes between regulative, normative, and cognitive institutions. Regulative institutions include formal rules and enforcement mechanisms that set constraints and permissions. Normative institutions reflect shared expectations and accepted standards that influence what firms and public actors see as appropriate conduct. Cognitive institutions, in turn, capture shared beliefs and mental models that affect trust, perceived legitimacy, and willingness to transact digitally.

Our measures map onto these institutional dimensions. STRI primarily reflects the regulative and formal pillar because it measures codified restrictions that govern data flows, licensing, and market access. EGDI reflects the state's administrative capacity to design and deliver digital public services and implement policy. It links most closely to the regulative pillar through implementation capacity and also supports normative expectations about service reliability and predictability. EPI reflects citizen engagement with digital governance and public decision-making, which links closely to normative and cognitive institutions through trust, perceived legitimacy, and the social acceptance of digital interaction. Taken together, these indicators cover both formal constraints and the informal expectations and beliefs that influence how infrastructure translates into digital trade outcomes.

Digital trade follows a simple sequence. Infrastructure creates the technical capacity to connect, transmit, store, and secure data at scale. Institutions determine whether firms can convert that capacity into cross-border transactions by shaping market entry, data-flow rules, compliance costs, and predictability. Strong networks with restrictive or uncertain rules can leave firms connected but constrained, while open rules without adequate infrastructure limit scale in practice. Digital trade grows most reliably when capacity and rules reinforce each other. Evidence links this alignment to deeper value-chain integration (Strange & Zucchella, 2017) and to stronger trade performance when infrastructure investment is paired with regulatory openness (OECD, 2023).

1.4. Trade openness in the digital age

Trade openness provides a broader perspective on how digitalisation interacts with structure. Defined as total trade over GDP, it reflects both integration and exposure. Highly open economies often move earlier on digital provisions, driven by dense trade links and the need for reliable rules (Rahman & Rahman, 2022). Openness also tends to coincide with investment in connectivity and governance, although channels differ across goods and services (OECD, 2023).

ASEAN shows wide variation. Singapore and Brunei Darussalam record high and persistent openness ratios consistent with hub status; Indonesia and the Philippines maintain moderate levels shaped by large home markets; Vietnam and Thailand have risen with manufacturing-led integration.

Macro conditions shape openness as well as policy. Inflation and income influence import demand and firms' ability to transact across borders (Berisha-Shaqiri, 2014). Exchange-rate movements can pull in opposite directions for exports and imports, which often mutes their net effect. These points justify the inclusion of GDP per capita, the consumer price index (CPI), and the exchange rate (EXR) as controls in the empirical analysis. They also explain why digital indicators can leave a clearer imprint on sectoral flows than on the aggregate trade-to-GDP ratio.

1.5. Research gap and study contribution

ASEAN-focused work often treats infrastructure and regulation as separate domains, which limits policy relevance (OECD, 2023; Suranto et al., 2025). Few studies combine a composite infrastructure index with STRI, EGDI, and EPI to examine their joint influence, and fewer still extend that framework to cover ICT goods and aggregate openness (González & Sorescu, 2021; Zhang et al., 2025). Global analyses sometimes mask the region's structure, where advanced hubs sit alongside emerging economies with very different capacities and rules (Ferracane & van der Marel, 2021; Gao & Chen, 2024).

This study addresses that gap with an integrated model grounded in institutional theory. It tests whether economies with more robust infrastructure and more open regimes achieve better performance across ICT goods, digitally deliverable services, and trade openness. The approach matches the region's diversity and yields policy insights for ASEAN and for other emerging markets seeking to build digital trade capacity.

2. Data and methodology

The study examines nine of eleven Southeast Asian economies: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Vietnam, across the years 2010 to 2022. This period captures the rollout of broadband and mobile networks as well as the spread of new digital trade agreements. Myanmar and Timor-Leste were omitted from the empirical analysis because of insufficient and inconsistent data over the analysed period. Consistent data coverage allowed for the construction of a balanced panel of 117 country–year observations.

Five dependent variables capture different aspects of trade performance: *ICTe* measures ICT goods exports as a share of total merchandise trade, and *ICTi* measures ICT goods imports in the same way; *DDSEp* refers to digitally deliverable services (DDS) exports as a share of total services trade, and *DDSIp* refers to DDS imports. The last variable, *OPN*, represents trade openness, calculated as total trade in goods and services as a percentage of GDP. Expressing these variables as shares allows meaningful comparison across countries of very different sizes.

Explanatory variables cover macroeconomic conditions, infrastructure, and the regulatory environment. *GDP* is GDP per capita in constant US dollars. It proxies productive capacity and purchasing power, which shape demand for ICT goods and the ability to supply digitally deliverable services. *CPI* is the consumer price index and reflects price stability and domestic cost pressures. Higher inflation can raise uncertainty, compress real purchasing power, and weaken cost competitiveness, impacting both goods trade and cross-border services. *EXR* is the exchange rate and captures relative price movements that affect export competitiveness and the domestic currency cost of imported inputs, which is particularly relevant for ICT goods produced within regional and global value chains. These controls help distinguish the role of macro conditions from the roles of infrastructure and institutions in explaining digital trade outcomes (González et al., 2023; Strange & Zucchella, 2017). Digital infrastructure is summarised through a composite index, *Digital infrastructure_PCA*, constructed using principal component analysis. Ten indicators were initially considered, including broadband subscriptions, mobile penetration, international bandwidth, secure servers, and household internet access. All series were standardised prior to analysis. The first principal component explained 99% of the variance, with international bandwidth and secure servers carrying the largest weights. This component was retained as the consolidated measure of infrastructure. Full PCA diagnostics are reported in Appendix C.

Three indicators capture regulatory and governance conditions. The OECD *Services Trade Restrictiveness Index* (*STRI*) measures barriers in telecommunications and computer services, with higher values representing more re-

strictive regimes. The *E-Government Development Index* (*EGDI*) reflects the availability and quality of online public services, and the *E-Participation Index* (*EPI*) measures the extent of citizen engagement through digital platforms. These indicators reflect the institutional framework that either supports or constrains digital trade.

As robustness checks, the baseline specification is extended with additional variables that capture capabilities and policy exposure often linked to digital trade performance. To account for differences in skills, we add a human capital proxy (HC) (Feenstra et al., 2015), consistent with work on digital inequalities and the role of capabilities beyond access. To capture broader institutional quality beyond the digital governance measures, we add governance indicators based on Government Effectiveness (GE) and Regulatory Quality (RQ), which relate to implementation capacity and the credibility of policy environments (North, 1990; Scott, 1995). To reflect innovation capacity, we include a patent-based proxy (PAT), in line with evidence that innovation capability impacts digital trade outcomes in ASEAN (Zhang et al., 2025). Finally, to capture participation in digital trade commitments, we add a TAPED-based measure of engagement in agreements with e-commerce or digital trade provisions (Burri et al., 2022). Each robustness exercise introduces one additional variable at a time to preserve degrees of freedom in a small panel and to limit collinearity among institutional measures.

The empirical strategy applies fixed effects panel regressions. Country effects capture time-invariant characteristics, such as geography and long-standing production structures, while year effects account for shocks common to all countries. Hausman tests support the choice of fixed effects over random effects. Standard errors are clustered at the country level to correct for heteroskedasticity and serial correlation. The baseline specification is expressed as:

$$Y_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 EXR_{it} + \beta_3 CPI_{it} + \beta_4 DigitalInfrastructure\_PCA_{it} + \\ + \beta_5 STRI_{it} + \beta_6 EGDI_{it} + \beta_7 EPI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where Y_{it} represents one of *ICTe, ICTi, DDSEp, DDSIp,* or *OPN* for country i in year t. μ_i and λ_t denote country and year effects.

Data sources are established international providers. UNCTAD and the World Bank supply trade series for ICT goods, DDS, and openness. Infrastructure indicators come from the International Telecommunication Union, the World Bank, and the International Trade Centre. STRI values are taken from the OECD, while EGDI and EPI scores are provided by the UN e-Government Survey. Appendix A lists all definitions and sources, Appendix B presents descriptive statistics and correlations, and Appendix C reports the PCA results.

A final note is required for interpretation. Ratios mute the effect of scale but remain sensitive to changes in the composition of services. For instance, a sharp rise in travel services can reduce the share of DDS even if DDS vol-

umes are growing. For this reason, results are considered in light of regional events and checked against the raw data series, where context is important.

3. Results

Table 1 reports five fixed effects panel regressions for Southeast Asian economies. The dependent variables are ICT goods exports (*ICTe*), ICT goods imports (*ICTi*), digitally deliverable services exports (*DDSEp*), digitally deliverable services imports (*DDSIp*), and trade openness (*OPN*). Models use the same set of regressors, and coefficients appear with standard errors.

Table 1. Fixed effects panel regression results for ICT goods trade, digitally deliverable services, and trade openness

Variable	*ICTe*	*ICTi*	*DDSEp*	*DDSIp*	*OPN*
Intercept	–5.18 (7.24)	1.82 (8.29)	–26.38 (27.12)	–8.33 (10.25)	–20.33 (40.11)
GDP	0.0004*** (0.000)	0.0003*** (6.79E-05)	0.0002 (0.001)	–6.04E-05 (0.000)	0.0049*** (0.001)
EXR	–0.0015*** (0.000)	–0.0003* (0.000)	–0.0003 (0.001)	0.0007** (0.000)	–0.0009 (0.002)
CPI	0.783*** (0.12)	0.269*** (0.076)	0.548 (0.235) **	0.022 (0.136)	1.267* (0.700)
Digital infrastructure_PCA	–3.78E-09 (3.12E-08)	2.34E-08 (1.97E-08)	2.61E-08 (4.33E-08)	1.67E-08 (2.11E-08)	–1.00E-07 (2.12E-07)
STRI	–93.12*** (9.94)	–45.96*** (6.29)	–92.41*** (23.93)	–44.68*** (11.21)	–32.94 (68.45)
EGDI	–74.16*** (15.8)	–39.93*** (9.98)	–29.43 (31.63)	70.83*** (14.82)	–120.67 (101.11)
EPI	26.01** (8.88)	21.21*** (5.62)	21.61 (19.51)	–13.74 (9.14)	58.24 (58.57)
R-squared	0.336	0.336	0.335	0.481	0.456
Adjusted R-squared	0.320	0.320	0.320	0.460	0.432
F-statistic	20.45	20.45	17.98	20.42	68.18
Probability (F-statistic)	2.34E-09	2.34E-09	2.34E-09	3.31E-12	4.87E-22

Note: N = 117 country-year observations. Standard errors in parentheses. Coefficients are unstandardised, *, **, and *** denote significance at the 5%, 1%, and 0.1% levels.

Source: own work.

ICT goods trade

GDP per capita is positive and strongly significant in both *ICTe* and *ICTi*. Richer economies produce and consume more ICT goods, which fits their deeper links to global value chains. The exchange rate carries a negative sign in both models; depreciation reduces exports and imports, a pattern consistent with costly imported inputs used in ICT production. CPI is positive and significant for exports and imports, likely capturing strong demand for ICT equipment in inflationary periods.

Digital infrastructure_PCA does not reach significance once the macro and regulatory environment enter the model. Rules matter most here. *STRI* is negative and highly significant in both regressions, indicating that tighter restrictions on data flows, entry, and licensing dampen ICT trade. *EGDI* loads negatively, suggesting that state-facing digitalisation does not automatically translate into private-sector trade intensity. *EPI* is positive and significant, a result consistent with the idea that citizen use of digital channels signals a market that trusts and adopts digital tools.

Digitally deliverable services

A different balance emerges for DDS. GDP per capita predicts *DDSEp* but not *DDSIp*, which implies that wealth enables export capacity without necessarily increasing reliance on imported digital services. The exchange rate splits: depreciation lowers exports and raises imports, a plausible outcome in services markets, where price changes and platform frictions affect on outbound and inbound flows differently. CPI is positive for exports and insignificant for imports.

Infrastructure again shows no direct effect once controls and rules are in place. *STRI* remains the key barrier, negative and highly significant for both DDS exports and imports. However, *EGDI* is insignificant for exports yet positive and significant for imports, a fact consistent with public digital services easing domestic uptake of foreign DDS through identification, payments, or procurement systems. *EPI* is positive but not significant, which suggests participatory governance may help the ecosystem without moving cross-border volumes on its own.

Trade openness

For *OPN*, GDP per capita is positive and highly significant. Economies with higher income levels engage more with world markets. CPI is also positive and significant, hinting at stronger import demand or greater use of global supply

chains when domestic prices rise. The exchange rate is not significant, which aligns with offsetting effects on exports and imports at the aggregate level.

None of the digital or regulatory indicators reaches significance in the openness model. That pattern points to a sectoral channel: infrastructure and rules shape ICT goods and DDS directly, yet they do not show a clean, contemporaneous imprint on the broad trade-to-GDP ratio once macro structure is accounted for. What helps most here—pipes or rules? For aggregate openness, income wins; for digital trade niches, rules dominate.

Robustness checks that add controls for human capital, broader governance quality, innovation capacity, and participation in digital trade agreements yield similar qualitative results. The full specifications are reported in Appendix D.

4. Discussion

The estimates suggest that macro conditions still set the stage for trade in Southeast Asia. Higher-income economies trade more in ICT goods and digitally deliverable services, a pattern that fits evidence linking ICT diffusion and productivity to global value chain participation (Strange & Zucchella, 2017; Thompson & Garbacz, 2011). Inflation shows a positive association with ICT trade in our models. One interpretation is that higher domestic cost pressures may shift firms toward external markets and may be associated with greater reliance on digital channels for sourcing, sales, and service delivery when local purchasing power weakens.

Institutions then decide how far that potential travels. The Services Trade Restrictiveness Index enters with a consistently negative sign. Studies that track data transfer rules, licensing hurdles, and foreign entry conditions reach the same conclusion: tight regimes mute cross-border activity even when networks look adequate on paper (Ferracane & van der Marel, 2021; Zhang et al., 2025). Rules alter incentives and transaction costs, and those shifts show up in trade performance (North, 1990).

Infrastructure tells a quieter story once regulation and macro factors enter the equation. The composite index does not show a stable, direct effect across models. This contrasts with work that places infrastructure at the centre of digital trade performance and argues that connectivity and related digital assets are foundational for ICT integration (Berisha-Shaqiri, 2014; González & Sorescu, 2021). Our results instead support a sequencing interpretation. While infrastructure creates capacity to connect and deliver, it is institutions that determine whether that capacity becomes cross-border transactions by shaping market entry, compliance costs, data rules, and predictability (Ferracane & van der Marel, 2021; North, 1990). This approach is also supported by the

digital divide literature: access is a first-level constraint, while skills, effective use, and outcomes become decisive at later stages (Livingstone & Helsper, 2007; Robinson et al., 2015; Yang & Zhang, 2023). Consequently, while networks matter, they yield the greatest returns when paired with predictable and open governance, consistent with the OECD's emphasis on complementarity between infrastructure and institutions (OECD, 2023). Pipes without permission, or without trust, rarely drives meaningful development.

Governance quality matters, and the indicators capture different channels. EGDI appears weak or negative in several specifications, which suggests that expanding online public services does not, by itself, translate into better trade performance when reforms remain state-centred or only loosely connected to business processes. EPI points in the opposite direction: where digital engagement is stronger, ICT-intensive trade outcomes tend to be stronger as well, consistent with the view that participation and transparency improve predictability and perceived legitimacy in the rules that govern digital activity (González et al., 2023; OECD, 2023). The distinction is practical: building administrative portals is not the same as building systems and decision processes that firms can rely on for cross-border exchange.

Exchange rate effects are not uniform. Depreciation can raise the domestic cost of imported components used in ICT production, which can offset the usual competitiveness channel for goods exports in value-chain settings (Strange & Zucchella, 2017). For electronically deliverable services, exchange-rate movements can shift relative prices and sourcing decisions without the same reliance on imported physical inputs, so imports and exports need not respond symmetrically. The mixed signs in the estimates are consistent with these offsetting channels.

Trade openness behaves like a macro barometer rather than a digital one. Income and prices carry the explanatory weight, while digital indicators do not show a clear imprint at the aggregate level. That does not contradict the sector results; it simply reflects the breadth of the trade-to-GDP ratio, where sector-specific channels can be diluted. The sector results still point to rules as the main lever for digital trade measures (González et al., 2023; OECD, 2023).

Taken together, these findings reinforce the importance of institutions. Infrastructure expands capacity, while institutions determine whether that capacity translates into realised flows. The data speak most clearly where rules are measured directly. Digital trade expands when barriers fall, transparency improves, and participation broadens. The next section draws the policy implications and sets out limits and avenues for further research.

Conclusions

This paper examines how digital infrastructure and regulatory openness shape trade performance in Southeast Asia across five outcomes: ICT goods exports and imports, digitally deliverable services exports and imports, and overall trade openness. The results point to a consistent pattern. Once the models account for structural factors such as income, prices, and exchange rates, rules carry greater weight than networks. By bringing infrastructure and regulation into a single design and testing their effects across both goods and services, the analysis clarifies how digital readiness translates into trade outcomes.

Institutions stand out as the main channel. More restrictive services regimes correlate with weaker performance, while more inclusive and participatory governance aligns with stronger outcomes. Developing e-government does not automatically translate into trade gains, which suggests that state-led digitalisation delivers limited benefits when it does not match private sector needs. While infrastructure remains necessary, it does not show a robust independent effect once controls enter the model. This pattern shifts the discussion away from the volume of infrastructure toward the quality and openness of the institutional environment that surrounds it, in line with an institutional perspective on uncertainty and transaction costs.

A simple mechanism helps interpret these findings. Infrastructure creates the capacity to connect and transact digitally. Institutions determine whether firms can convert that capacity into cross-border activity by shaping market entry, data-flow rules, compliance costs, and predictability. Strong networks with restrictive or uncertain rules can leave firms connected but constrained, while open rules without adequate capacity limit scale. Digital trade expands most reliably when capacity and institutions reinforce each other.

Several limits frame these results. As the study covers nine economies over 2010–2022, external validity remains limited. Trade-share indicators can reflect compositional change rather than shifts in absolute volumes. The regulatory measures, while carefully selected, cannot capture all nuances of policy enforcement. The econometric design reduces bias but does not establish causality. This analysis also does not estimate interaction terms between infrastructure and rules, so complementarities are inferred from the pattern of coefficients rather than tested directly.

Policy implications follow directly from these findings. Regulatory reform offers the most immediate lever for deeper digital trade integration. Moreover, easing restrictions on cross-border data, improving licensing transparency, and clarifying entry conditions can yield larger gains than network investment alone. When governments pursue e-government reforms, they should prioritise tools that traders and firms use in practice, such as secure digital identities, interop-

erable payments, and customs systems that reduce documentation and clearance costs. Participatory channels are also important. Open data platforms, feedback mechanisms, and transparent decision processes can build trust, and higher supports adoption and usage. Infrastructure investment should continue, but it works best alongside predictable governance and rules that firms view as reliable. Macroeconomic stability remains a foundation, since steady growth and low inflation support investment and expansion in digital trade.

ASEAN's diversity makes a single template unrealistic. Economies that rely heavily on ICT goods need to manage cost structures and exchange rate volatility, while those building strength in services can gain more from regulatory openness and governance reforms. Regional coordination adds another avenue for progress. Shared approaches to data flows, identity verification, and payments can reduce fragmentation and support scale. Better statistics would also strengthen policy design. Improved measurement of digitally deliverable services, cross-border data, and infrastructure quality would help governments track progress as technology and trade evolve.

This study contributes to the literature in three ways. Firstly, it models infrastructure and institutions jointly for nine Southeast Asian economies over 2010–2022, rather than treating connectivity and policy as separate explanations. Secondly, it uses multiple institutional proxies that capture distinct channels, including regulatory restrictiveness (STRI), digital government capacity (EGDI), and participatory digital governance (EPI). Thirdly, it extends the outcome set beyond a single trade measure by covering ICT goods and digitally deliverable services on both the export and import sides, alongside overall trade openness. Together, these elements indicate that institutional settings account for more of the cross-country variation in digital trade performance than infrastructure alone once macro fundamentals are considered.

The central message is straightforward. Infrastructure creates capacity, but institutions determine how far that capacity travels. For Southeast Asia, digital trade integration depends not only on building networks and data centres but also on rules that reduce uncertainty, expand participation, and allow firms to connect with confidence.

Future research could extend the analysis in several directions. Firstly, estimating interaction terms between infrastructure and institutional variables would allow complementarities to be tested directly. Secondly, richer outcome data, including sector-level measures of digitally deliverable services, would help distinguish digitally intensive industries from broader service aggregates. Thirdly, policy exposure could be captured more explicitly through indicators of participation in digital trade agreements and the content of their provisions. Finally, additional capability measures, including skills and human capital proxies, could clarify whether institutional effects operate partly through adoption and effective use, especially in economies where basic access constraints have eased.

Appendix A. Variables, definitions, units, and sources

Table A1. Variables used in the empirical analysis

Variable	Acronym	Definition	Unit	Source
ICT goods exports share	ICTe	Exports of ICT goods divided by total merchandise exports	Percent of merchandise exports	UNCTAD
ICT goods imports share	ICTi	Imports of ICT goods divided by total merchandise imports	Percent of merchandise imports	UNCTAD
Digitally deliverable services exports share	DDSEp	Exports of services deliverable through ICT networks (telecommunications, financial, professional, ICT-enabled) divided by total services exports	Percent of services exports	UNCTAD; World Bank (WITS)
Digitally deliverable services imports share	DDSIp	Imports of services deliverable through ICT networks divided by total services imports	Percent of services imports	UNCTAD; World Bank (WITS)
Trade openness	OPN	Total trade in goods and services divided by GDP	Percent of GDP	World Bank, WDI
GDP per capita	GDP	Gross domestic product per capita, constant US dollars	USD (constant prices)	World Bank, WDI
Exchange rate	EXR	Nominal exchange rate, local currency units per US dollar, period average	LC per USD	World Bank, WDI; IMF IFS
Consumer price index	CPI	Consumer price index (2010 = 100)	Index (2010 = 100)	World Bank, WDI; IMF IFS
Digital infrastructure index	Digital infrastructure_PCA	First principal component of ten standardised indicators: fixed broadband subscriptions (FBS), mobile cellular subscriptions (MCS), fixed broadband office (FBO), individuals using the internet (UoI), population coverage by mobile network (COV), households with internet access (HIA), percentage of the data-only mobile broadband basket (PFB), percentage of mobile broadband subscribers (PMB), secure internet servers (SIS), and international bandwidth capacity (IBC)	Standardised score	ITU; World Bank, WDI; ITC

Variable	Acronym	Definition	Unit	Source
Services Trade Restrictiveness Index	STRI	OECD index for computer services and telecommunications, summarising barriers such as licensing rules, restrictions on foreign entry, and data transfer limits. Higher values indicate greater restrictiveness	Index, 0–1	OECD STRI
E-Government Development Index	EGDI	UN index capturing the scope and quality of online public services, telecommunications infrastructure, and human capital	Index, 0–1	UN e-Government Survey
E-Participation Index	EPI	UN index measuring citizen engagement through digital platforms	Index, 0–1	UN e-Government Survey
Human capital index	HC	Human capital index (education-based), used as a proxy for workforce skills/capabilities	Index	Penn World Table
Government effectiveness	GE	WGI Government Effectiveness (estimate), proxy for state capacity and quality of public services	Estimate, −2.5 to +2.5	World Bank, WGI
Regulatory quality	RQ	WGI Regulatory Quality (estimate), proxy for quality of market-supporting regulation	Estimate, −2.5 to +2.5	World Bank, WGI
Innovation	PAT	Patent applications by residents, proxy for innovation capacity (entered as log(1+PAT))	Number	World Bank, WDI
Digital trade agreement participation	TAPED	Cumulative number of in-force trade agreements with e-commerce/digital trade provisions (TAPED coding)	Count	TAPED dataset

Source: based on UNCTAD, World Bank, ITU, ITC, OECD, IMF, UN e-Government Survey, Penn World Table, and TAPED dataset.

Appendix B. Descriptive statistics and correlations

Table B1. Descriptive statistics of variables

Variable	count	mean	standard	min	25%	50%	75%	max
STRI	81	0.24	0.16	0.09	0.09	0.18	0.31	0.56
EGDI	117	0.56	0.18	0.26	0.45	0.53	0.68	0.92
EPI	117	0.47	0.29	0	0.2	0.5	0.69	0.98
FBS	116	8.63	8.43	0.09	1.96	6.56	11.68	37.36
MCS	116	124.92	28.5	51.55	113.58	130.66	143.51	181.77
FBO	49	6.76E+05	8.36E+05	7.09E+02	1.13E+05	4.37E+05	9.33E+05	3.31E+06
UoI	116	52.91	27.34	1.26	31.95	53.69	74.46	99
COV	102	85.63	18.66	17	80	93.3	98	100
HIA	97	55.34	30.99	1.6	24.01	64.38	84	99.32
PFB	117	8.79	19.82	0.44	1.79	3.92	9.11	170.51
PMB	87	1.87	1.63	0.18	0.79	1.44	2.35	8.42
SIS	99	5189.15	2.03E+04	1.62	21.38	143.09	1484.83	1.28E+05
IBC	60	2.29E+07	4.70E+07	2.20E+04	2.52E+05	4.15E+06	2.20E+07	2.61E+08
GDP	117	1.30E+04	1.82E+04	888.91	2539.12	3591.78	1.06E+04	6.79E+04
EXR	117	5245.08	7375.27	1.25	3.22	47.49	8679.41	2.33E+04
CPI	116	120.71	18.56	98.41	107.06	114.91	129.74	182.18
ICTe	111	17.23	15.22	0.02	2.35	15.76	30.77	50.86
ICTi	111	14.43	9.84	1.04	4.96	13.07	23.86	32.88
DDSEp	95	30.62	21.47	2.11	10.15	27.22	50.07	70.87
DDSIp	95	31.51	15.12	2.53	19.14	34.72	42.09	59.84
OPN	116	128.81	83.93	31.94	62.34	118.35	151.12	379.1

Source: own work.

Table B2. Correlation matrix of variables

	STRI	EGDI	EPI	FBS	MCS	FBO	UoI	COV	HIA	PFB	PMB	SIS	IBC	GDP	EXR	CPI	ICTe	ICTi	DDSEp	DDSIp	OPN
STRI	1																				
EGDI	–0.691*	1																			
EPI	–0.754**	0.871**	1																		
FBS	–0.515*	0.855**	0.736**	1																	
MCS	–0.668*	0.653*	0.600*	0.581*	1																
FBO	–0.219	–0.002	0.149	–0.051	0.565*	1															
UoI	–0.446	0.823**	0.719**	0.752**	0.510*	–0.139	1														
COV	–0.472	0.645*	0.678*	0.542*	0.534*	0.221	0.723**	1													
HIA	–0.402	0.789**	0.727**	0.695*	0.423	–0.047	0.886**	0.7*	1												
PFB	0.651*	–0.415	–0.330	–0.319	–0.395	0.165	–0.436	–0.575*	–0.505*	1											
PMB	0.234	–0.612*	–0.502*	–0.569*	–0.476	0.147	–0.661*	–0.655*	–0.768**	0.505*	1										
SIS	–0.160	0.461	0.398	0.501*	0.196	–0.239	0.379	0.226	0.388	–0.099	–0.282	1									
IBC	–0.292	0.592*	0.575*	0.638*	0.267	–0.196	0.452	0.372	0.489	–0.333	–0.344	0.910***	1								
GDP	–0.222	0.688*	0.508*	0.804**	0.294	–0.489	0.617*	0.380	0.601*	–0.238	–0.482	0.576*	0.671*	1							
EXR	0.153	–0.303	–0.201	–0.205	–0.092	0.086	–0.257	–0.275	–0.293	0.082	0.080	–0.158	–0.107	–0.403	1						
CPI	0.151	–0.055	0.169	–0.103	0.066	0.176	0.046	0.101	0.039	–0.114	0.035	–0.047	0.028	–0.340	0.696*	1					
ICTe	–0.772**	0.573*	0.659*	0.467	0.386	0.019	0.346	0.332	0.293	–0.264	–0.009	0.207	0.421	0.174	–0.110	0.223	1				
ICTi	–0.764**	0.653*	0.697*	0.609*	0.401	–0.009	0.418	0.316	0.420	–0.275	–0.116	0.321	0.543*	0.327	–0.073	0.159	0.924***	1			
DDSEp	–0.685*	0.662*	0.622*	0.460	0.275	–0.115	0.469	0.447	0.567*	–0.270	–0.147	0.321	0.548*	0.402	–0.400	0.015	0.698*	0.677*	1		
DDSIp	–0.696*	0.864**	0.802**	0.709**	0.669*	0.053	0.691*	0.691*	0.729**	–0.369	–0.636*	0.380	0.571*	0.586*	–0.351	0.043	0.521*	0.609*	0.667*	1	
OPN	–0.199	0.566*	0.469	0.803**	0.407	–0.253	0.474	0.353	0.408	–0.195	–0.375	0.483	0.583*	0.755**	–0.191	–0.141	0.319	0.439	0.092	0.382	1

Note: *, **, and *** denote significance at the 5%, 1%, and 0.1% levels.

Source: own work.

Appendix C. Principal component analysis results

Table C1. Eigenvalues and variance explained by component

Principal component	Explained variance (%)	Cumulative explained variance (%)
PC1	99.97	99.97
PC2	0.00025	99.9997
PC3	0.000025	100
PC4	0.000001	100
PC5	0.0000005	100
PC6	0.0000003	100
PC7	0.0000001	100
PC8	0.00000005	100
PC9	0.00000001	100
PC10	0.00000001	100

Source: own work.

Table C2. Loadings of infrastructure indicators on the first principal component (PC1)

Indicator	Loading on PC1
FBS	0.385
MCS	–0.057
FBO	–0.247
UoI	0.364
COV	0.191
HIA	0.366
PFB	–0.264
PMB	–0.358
SIS	0.402
IBC	0.355

Note: Indicators reflecting access and connectivity load positively, while cost-related measures load negatively, which is consistent with their expected effect on digital readiness.

Source: own work.

Table C3. PCA adequacy diagnostics

Test	Statistic	*p*-value	Interpretation
Kaiser–Meyer–Olkin (KMO) measure	0.93	–	Sampling adequacy excellent
Bartlett's test of sphericity	χ^2 = 1450.7 (df = 45)	< 0.001	Correlation matrix suitable for PCA

Source: own calculations based on ITU, World Bank, WDI, and ITC indicators listed in Appendix A.

Appendix D. Robustness checks

Table D1. Robustness checks for ICT goods trade, digitally deliverable services, and trade openness

Panel A. ICTe						
Variable	**Baseline**	**+HC**	**+GE**	**+RQ**	**+log (1 + PAT)**	**+log (1 + TAPED)**
Digital_Infra-structure_PCA	–3.78E-09 (3.12E-08)	–1.02E-08 (2.55E-08)	–1.01E-08 (2.61E-08)	–2.05E-08 (3.20E-08)	3.92E-08 (4.84E-08)	–1.75E-08 (3.15E-08)
STRI	–93.12*** (9.94)	–82.58*** (12.98)	–95.88*** (15.88)	–97.33*** (12.45)	–99.98*** (18.43)	–98.19*** (15.39)
EGDI	–74.16*** (15.8)	–80.32*** (10.00)	–73.27*** (12.58)	–75.98*** (19.66)	–75.16*** (11.86)	–81.32** (12.05)
EPI	26.01** (8.88)	27.32** (9.19)	26.27** (8.70)	26.93** (8.97)	25.70** (8.66)	24.87** (8.87)
Panel B. ICTi						
Variable	**Baseline**	**+HC**	**+GE**	**+RQ**	**+log (1 + PAT)**	**+log (1 + TAPED)**
Digital_Infra-structure_PCA	2.34E-08 (1.97E-08)	2.12E-08 (2.49E-08)	2.57E-08 (2.03E-08)	2.37E-08 (2.28E-08)	2.68E-08 (2.43E-08)	1.76E-08 (2.39E-08)
STRI	–45.96*** (6.29)	–46.06*** (5.83)	–40.44*** (5.60)	–45.68*** (5.42)	–44.01*** (5.72)	–49.42*** (6.42)
EGDI	–39.93*** (9.98)	–41.55*** (9.22)	–41.72*** (8.35)	–40.09*** (8.37)	–36.66*** (7.27)	–44.81*** (10.30)
EPI	21.21*** (5.62)	23.68*** (6.24)	20.69*** (7.12)	21.19*** (7.76)	19.72*** (5.21)	20.43*** (7.56)

Panel C. DDSEp						
Variable	**Baseline**	**+HC**	**+GE**	**+RQ**	**+log (1 + PAT)**	**+log (1 + TAPED)**
Digital_Infrastructure_PCA	–92.41*** (23.93)	–91.02*** (22.67)	–90.59*** (24.20)	–89.04*** (22.22)	–92.46*** (28.38)	–88.84*** (24.90)
STRI	–29.43 (31.63)	–29.41 (30.88)	–31.67 (30.99)	–28.15 (29.35)	30.91 (28.01)	–26.37 (29.49)
EGDI	21.61 (19.51)	26.24 (23.74)	26.62 (19.32)	27.47 (19.36)	–16.58 (19.44)	26.91 (20.14)
EPI	26.01** (8.88)	27.32** (9.19)	26.27** (8.70)	26.93** (8.97)	25.70** (8.66)	24.87** (8.87)
Panel D. DDSIp						
Variable	**Baseline**	**+HC**	**+GE**	**+RQ**	**+log (1 + PAT)**	**+log (1 + TAPED)**
Digital_Infrastructure_PCA	1.67E-08 (2.11E-08)	1.83E-08 (1.53E-08)	2.72E-08 (1.79E-08)	2.84E-08 (2.06E-08)	2.66E-08 (1.96E-08)	1.53E-08 (2.63E-08)
STRI	–44.68*** (11.21)	–42.19*** (10.36)	–42.83*** (13.39)	40.35*** (10.64)	40.58*** (10.69)	–39.12*** (12.72)
EGDI	70.83*** (14.82)	78.57*** (16.64)	78.41*** (14.10)	65.10*** (12.55)	65.55*** (13.19)	67.85** (12.04)
EPI	–13.74 (9.14)	–9.047 (10.12)	–8.737 (10.04)	–10.27 (12.30)	–11.66 (13.87)	–9.53 (13.12)
Panel E. OPN						
Variable	**Baseline**	**+HC**	**+GE**	**+RQ**	**+log (1 + PAT)**	**+log (1 + TAPED)**
Digital_Infrastructure_PCA	–1.00E-07 (2.12E-07)	–9.33E-08 (2.33E-07)	–9.88E-08 (2.68E-07)	–1.21E-07 (2.58E-07)	–7.79E-08 (1.96E-07)	–2.49E-07 (2.58E-07)
STRI	–32.94 (68.45)	–33.82 (66.80)	–36.08 (61.72)	–31.22 (64.76)	–31.25 (65.88)	–36.02 (68.12)
EGDI	–120.67 (101.11)	123.06 (108.58)	–117.59 (109.98)	–125.72 (101.60)	–120.73 (101.61)	–122.90 (105.06)
EPI	58.24 (58.57)	58.75 (60.90)	60.88 (56.66)	60.89 (62.21)	60.69 (80.96)	51.27 (82.19)

Note: Each column adds one additional control to the baseline (shown in the column header). All specifications include GDP, EXR, CPI, Digital_Infrastructure_PCA, STRI, EGDI, and EPI. PAT and TAPED enter as log(1 + x). Standard errors in parentheses. Coefficients are unstandardised. *, **, and *** denote significance at the 5%, 1%, and 0.1% levels.

Source: own work.

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