RESEARCH PAPER

# Internet Use, Government Effectiveness and Science-and-Engineering Publication Intensity: Panel Evidence from 164 Economies, 2006–2023

**Zile Fan[1]* , Chandra Mohan Vasudeva Panicker[1]**
[1] School of Business & Management, Lincoln University College, Malaysia
* *Corresponding author: full121314@163.com*

**Structured abstract**

**Purpose –** We examine the associations of population-level internet use and government effectiveness with science-and-engineering publication intensity, and test whether the association with internet use varies with government effectiveness.

**Design/methodology/approach –** Using 2,811 observations for 164 economies from 2006 to 2023, we estimate economy and year fixed-effects models with one-year lags and economy-clustered standard errors. We assess sensitivity to alternative time controls, lags, outcome models, digital measures and samples.

**Findings –** Internet use and government effectiveness are each positively associated with publication intensity. Their interaction is positive in the baseline model and several timing and trend checks, but it weakens or changes sign with region-by-year effects, first differences, fixed broadband and PPML with a population offset. We therefore find only model-dependent evidence of complementarity and make no causal claim.

**Originality/value –** The study shifts attention from patents to scientific publishing and distinguishes short-run changes in government effectiveness from persistent governance differences. It thereby defines the empirical limits of digital–institutional complementarity in national research systems.

**Research limitations/implications –** The analysis relies on aggregate indicators with known coverage and perception-related limitations; lags and fixed effects do not establish causality.

**Practical implications –** The results favour evaluating connectivity and administrative reforms jointly, but they do not identify the effect of either policy.

**Keywords:** internet use; government effectiveness; scientific publishing; national innovation systems; public management; institutional complementarity; panel data; open data

**How to cite this article:** Zile Fan. Internet Use, Government Effectiveness and Science-and-Engineering Publication Intensity: Panel Evidence from 164 Economies, 2006–2023. Int J Drug Deliv Technol. 2026;16(77s):1761-1773. DOI: 10.25258/ijddt.16.77s.200.

## 1. Introduction

Scientific publications are produced by research organisations, but they also circulate knowledge through the wider innovation system. They codify findings, expose them to scrutiny and provide material that firms, public agencies and other researchers can use. Yet the volume and disciplinary breadth of scientific production remain highly uneven across countries, with consequences for competitiveness and regional inequality (Abramo and D'Angelo, 2024; Patelli *et al.*, 2023). The relevant management question is how institutions coordinate dispersed resources to produce scientific publications, particularly as research increasingly relies on digital search, data exchange, remote collaboration, computing and electronic dissemination.

As internet use spreads, more people and organisations can reach digital information and communication networks. Population adoption, however, is not the same as research-grade connectivity, digital skill or scientific infrastructure. Wider use may lower search and coordination costs and broaden participation, but it does not allocate grants, maintain laboratories or make research policy credible. Digital networks support collaboration and innovation (Wernsdorf *et al.*, 2022), yet their returns differ with education, development stage and ecosystem configuration (Afawubo and Noglo, 2022; Uyar *et al.*, 2023). The resulting question is straightforward: does the association between internet use and scientific publishing vary with government effectiveness?

Government effectiveness provides one way to examine this institutional variation. Although the Worldwide Governance Indicators (WGI) measure does not capture science administration directly, it reflects perceived public-service quality, policy implementation and the credibility of government commitments (World Bank, 2025)—features that may affect funding stability, inter-agency coordination and public digital services. Prior studies associate government efficiency and institutional quality with innovation outcomes (Wen *et al.*, 2021; Danta and Rath, 2024; Singh *et al.*, 2025), but less is known about whether government effectiveness conditions the internet-use–publishing relationship across a broad global panel.

A closely related benchmark is Pudasaini and Kornwattanakit (2026), who use composite measures of digital connectivity and institutional–legal strength to explain patent applications and grants in 65 countries during 2010–2023. They report positive additive associations for patent applications, but the marginal contribution of connectivity declines at higher institutional strength; results for grants are weaker and more context-dependent. We examine whether that pattern generalises to an upstream outcome. The analysis studies population internet use, government effectiveness and publication intensity across 164 economies, and tests whether the interaction changes when log per-capita output is replaced with a population-offset count model. The contribution lies in distinguishing innovation stage, institutional construct and outcome scale, not simply in extending the sample.

The article makes two contributions. First, it links national innovation-systems research to public management by distinguishing broad internet use from the government's ability to implement policy and deliver services. Second, it tests whether their association with scientific publishing persists across within-economy, region-by-year and count-data models. The comparison separates the direct associations that remain comparatively stable from the interaction that depends more heavily on modelling choices.

The baseline estimates show positive associations for lagged internet use, lagged government effectiveness and their interaction. The interaction remains positive with economy-specific trends, a two-year lag, two-way clustered inference, the exclusion of 2020–2021 and alternative winsorisation. It is imprecise with region-by-year effects and first differences, turns negative and imprecise when fixed broadband replaces internet use, and is also negative and imprecise in the publication-count Poisson model. Taken together, the estimates provide limited evidence of complementarity; they do not identify causal amplification.

## 2. Theoretical background, hypotheses and research question

### *2.1 Digital and institutional inputs in national innovation systems*

The national innovation-systems tradition views innovation as an outcome of interactions among firms, universities, public research organisations, financial bodies and government agencies rather than as a linear consequence of isolated research spending. Early formulations emphasised historically embedded institutional arrangements and interactive learning (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Later work formalised national innovative capacity as the ability to produce and commercialise a stream of innovations, linking common infrastructure, cluster conditions and linkages (Furman *et al.*, 2002). For this study, the key implication is that inputs matter only when organisations can access, coordinate and use them to produce observable outputs.

In this article, that process comprises the organisational linkages and implementation routines through which system inputs become codified knowledge. It is narrower than national innovative capacity, which also encompasses appropriation and commercialisation, and it is distinct from technical efficiency, which requires an explicit input–output frontier. Publication intensity is accordingly not labelled research productivity: articles per million residents measure the scale of codified output relative to population, not output per researcher or per unit of R&D expenditure. At the organisational level, Zhang and Murad (2026) similarly show that collaborative resources are associated with venture performance through an intervening responsible-innovation process. Their firm-level setting is not directly comparable, but it illustrates the limited proposition that resources need not translate automatically into outcomes.

Recent studies likewise show that resource endowments alone do not determine national innovation performance. Strong input endowments do not guarantee efficient national innovation performance (Erdin and Çağlar, 2023), and dynamic-network approaches separate resource acquisition from intermediate and final outputs (Anouze *et al.*, 2024). European evidence shows divergent productivity and catching-up paths (Zabala-Iturriagagoitia *et al.*, 2021), while comparisons across developing economies reveal that technological catch-up depends on the structure of the system, not only the quantity of inputs (Ndicu *et al.*, 2024). National systems also follow balanced, imbalanced, catching-up and trapped trajectories (Lee *et al.*, 2021). Consequently, internet diffusion should not be theorised as a sufficient innovation input; it is an enabling condition whose value depends on complementary arrangements.

Scientific publishing is an upstream output of these national arrangements. It captures codified contributions in covered science and engineering fields, but not their citation impact, novelty, societal value or commercial use. National publication intensity also reflects the ability to assimilate and apply research investment (Lancho-Barrantes *et al.*, 2021) and policy choices that can reproduce or reduce regional asymmetries (Pinedo-López *et al.*, 2025). It is therefore a useful but limited indicator of knowledge production rather than a complete proxy for scientific capacity or innovation.

### *2.2 Internet use and the research environment*

Internet use can influence the organisational environment for knowledge production through four channels. First, electronic access can reduce the cost and delay of locating literature, data, software and potential collaborators. Second, communication platforms can expand the feasible geography and frequency of collaboration. Third, digital dissemination increases the speed at which working papers, code and findings reach specialised communities. Fourth, widespread use can enlarge the domestic pool of students, suppliers and organisations able to interact with research institutions. Historical evidence from BITNET provides a particularly clear collaboration mechanism: early network access altered scholarly connections and science-based inventive activity (Wernsdorf *et al.*, 2022).

Existing research offers convergent but incomplete evidence. One strand links ICT and digitalisation to entrepreneurship and national competitiveness (Afawubo and Noglo, 2022; Dabbous *et al.*, 2023; Zhang *et al.*, 2023). A second shows that digital infrastructure contributes to innovation as part of wider bundles of education, institutions and system linkages (Prokop *et al.*, 2021; Duarte and Carvalho, 2024; Huang *et al.*, 2024). A third connects network access more directly to scholarly collaboration and research performance (Wernsdorf *et al.*, 2022; Uyar *et al.*, 2023). Together, these studies establish a plausible digital–knowledge link but do not show whether within-economy internet diffusion is associated with publication intensity or whether government effectiveness changes that association.

The focal World Development Indicator measures the share of people who used the internet from any location during the previous three months. It does not identify scientists, connection quality, affordability or advanced research use (World Bank, 2026b). Internet use is therefore treated as a contextual indicator of broad digital participation. An increase in the user share is not assumed to translate one-for-one into additional authors; it may instead deepen the service, learning, supplier and collaboration environment surrounding research organisations.

***H1.*** *Within economies, higher lagged internet use is positively associated with science-and-engineering publication intensity.*

*2.3 Government effectiveness in the research environment*

Government effectiveness can matter directly for publishing because research systems are organisationally dependent on credible routines. Grant allocation, procurement, visa administration, data access, higher-education regulation, research evaluation and the maintenance of public digital services all require coordination across agencies. Where policy formulation and implementation are reliable, universities and laboratories can plan longer-horizon projects, form partnerships and devote fewer resources to administrative uncertainty. Cross-country evidence associates greater government efficiency with innovation (Wen *et al.*, 2021), and institutional factors including government effectiveness are significant components of national innovation systems (Singh *et al.*, 2025).

The argument does not imply that a broad perception index measures science-policy competence. Public-sector digital transformation can raise administrative efficiency, but effects differ by organisational setting (Yang *et al.*, 2024). E-government development does not automatically produce governance improvement (Zou *et al.*, 2023), and public agencies adopt enhancement, anticipatory, adaptive and persistence-oriented digital innovation strategies under different conditions (Guenduez *et al.*, 2025). Government effectiveness is consequently interpreted as a general credibility and implementation environment within which research organisations operate.

Government effectiveness may matter on two time horizons. Within-economy improvements can reduce current implementation frictions, whereas a durable governance context may allow research organisations to accumulate routines, trust and inter-organisational networks. The first concerns institutional change; the second concerns persistent system context. The within–between decomposition in Section 3.4 distinguishes these possibilities rather than assigning both to a single coefficient.

***H2.*** *Within economies, higher lagged government effectiveness is positively associated with science-and-engineering publication intensity.*

*2.4 Complementarity versus substitution*

At aggregate level, complementarity is treated as a testable associational pattern rather than an identified production parameter. A positive interaction would mean that the within-economy association between internet use and publication intensity is stronger at higher government effectiveness. One possible mechanism is coordinated use: broad digital participation widens access to information and collaboration, while reliable public services and implementation routines help research organisations exploit those opportunities. Evidence that institutional configurations jointly shape national innovation capability is consistent with this account (Erzurumlu *et al.*, 2022).

A substitution account predicts that the digital association weakens as government effectiveness rises. Direct access to international knowledge, remote collaboration and decentralised coordination may partly bypass administrative frictions; conversely, high-capacity systems may already have well-functioning research networks, leaving smaller marginal gains from further internet diffusion. Pudasaini and Kornwattanakit (2026) sharpen this alternative by showing diminishing marginal returns to connectivity at higher institutional–legal strength in patent models. Because publications occupy an earlier and less appropriable stage of knowledge production, their average interaction cannot simply be inferred from patent evidence.

***RQ1.*** *How does government effectiveness condition the within-economy association between internet use and science-and-engineering publication intensity?*

The answer may also depend on the outcome scale. Log publication intensity emphasises proportional differences and limits the leverage of very large publishing systems, whereas population-offset PPML estimates expected aggregate output and accommodates zero counts directly. Agreement across the two models would indicate a more general conditioning pattern; disagreement would identify an estimand boundary rather than a mechanically failed robustness test.

Figure 1 summarises the conceptual model. It distinguishes population internet use from the organisational processes that produce publications and allows government effectiveness to have both a direct association and a conditioning role. The arrows state theoretical expectations; the aggregate panel does not observe the organisational mechanisms themselves.

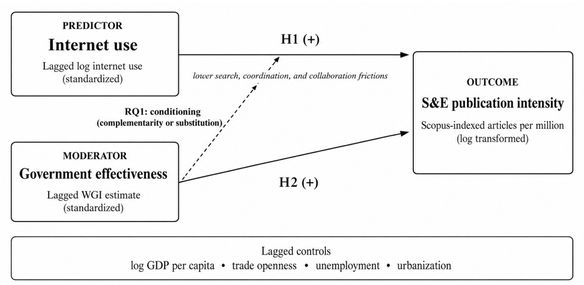


***Figure 1. Internet use, government effectiveness and scientific publishing***

*Source: Authors' conceptualisation. Solid arrows denote the direct hypotheses; the bracketed path denotes the open conditioning question in RQ1.*

## 3. Data and methods

### *3.1 Research design and sample*

The empirical design is an economy-panel study using public annual data. The estimation period is 2006–2023. Data are retrieved from the World Bank Application Programming Interface for World Development Indicators (WDI) and from the Data360 release of the WGI. The pull begins in 2004 so that lags and alternative two-year specifications can be constructed without truncating the intended start year. World Bank aggregate entities are excluded from estimation, country identifiers are merged by ISO3 code, and every ISO3-year is required to be unique. No missing outcome or explanatory values are interpolated.

The baseline complete-case sample contains 2,811 economy-year observations from 164 economies. It spans 18 years, with a median of 18 usable observations per economy; 134 economies are observed in every estimation year and the minimum retained series length is five. The sample contains 953 observations from 53 high-income economies, 838 from 49 upper-middle-income economies, 732 from 43 lower-middle-income economies and 288 from 19 low-income economies. It is geographically broad but not statistically representative of all economies: coverage depends especially on trade and unemployment data, and the extended research-resource indicators produce much smaller samples.

The unit of analysis is an economy-year, and the design uses temporal ordering rather than a claim of treatment assignment. Focal and control variables are lagged one year; a two-year-lag specification examines a longer research-production interval. Economy fixed effects remove time-invariant differences such as language, geography and persistent research traditions, while year fixed effects absorb global shocks common to the sample. These choices improve comparability but do not remove reverse causality, time-varying omitted variables or cross-border spillovers. Results are consequently described as within-economy associations.

### *3.2 Measures and public sources*

Table I reports the variable definitions, transformations and data sources. All continuous source variables are winsorised at the 1st and 99th percentiles on the pooled 2004–2023 source panel before transformation and lag construction. The final estimation sample contains no World Bank aggregates, although the pooled source panel used to set the winsorisation cut-offs is calculated before their final deletion. The focal variables are standardised within each estimation sample, and their interaction is the product of those z-scores.

***Table I. Variable definitions, operationalisation and public sources***

| Construct | Indicator | Operationalisation | Primary source |
|---|---|---|---|
| Publication intensity | IP.JRN.ARTC.SC / SP.POP.TOTL | ln[1 + winsor(S&E articles per million residents)] | NSF/NCSES via WDI; UN population |
| Internet use | IT.NET.USER.ZS | t−1 ln[1 + winsor(% population using internet)] | ITU via WDI |
| Government effectiveness | GOV_WGI_GE; WGI_EST | t−1 winsor(revised governance estimate); z-score | World Bank WGI 2025 revision |
| GDP per capita | NY.GDP.PCAP.KD | t−1 ln[winsor(constant 2015 US$)] | World Bank national accounts via WDI |
| Trade openness | NE.TRD.GNFS.ZS | t−1 winsor(exports + imports as % GDP) | World Bank/OECD via WDI |
| Unemployment | SL.UEM.TOTL.ZS | t−1 winsor(% labour force; modelled estimate) | ILO via WDI |
| Urban population | SP.URB.TOTL.IN.ZS | t−1 winsor(% total population) | UN Population Division via WDI |
| Tertiary enrolment | SE.TER.ENRR | t−1 winsor(gross enrolment ratio) | UNESCO UIS via WDI |
| R&D expenditure | GB.XPD.RSDV.GD.ZS | t−1 winsor(% GDP) | UNESCO UIS via WDI |

| Construct | Indicator | Operationalisation | Primary source |
|---|---|---|---|
| Researchers | SP.POP.SCIE.RD.P6 | t−1 winsor(researchers per million people) | UNESCO UIS via WDI |

***Note:*** *S&E = science and engineering; WDI = World Development Indicators; WGI = Worldwide Governance Indicators; UIS = UNESCO Institute for Statistics. All explanatory variables are lagged one year in the baseline. Internet use and government effectiveness are z-standardised before multiplication. Data accessed 16 August 2026.*

The dependent variable uses WDI series IP.JRN.ARTC.SC. Its source is the US National Science Foundation's Science and Engineering Indicators and Scopus coverage; the count comprises peer-reviewed journal articles and selected conference proceedings in science and engineering fields, with fractional country attribution and gap-filling in the published series (World Bank, 2026a). It excludes many humanities and social-science outputs, does not measure citations or quality, and is affected by Scopus language and source coverage. Same-year population is used as the denominator. There are 23 zero economy-years in the outcome universe, motivating the natural logarithm of one plus articles per million residents.

Let *SP* denote publication intensity, *ART* the article count and *POP* the same-year population. The transformation is formalised in equation (1).

$$SP_{it} = \ln[1 + \frac{ART_{it}}{POP_{it}} \times 10^6] \quad (1)$$

Internet use is WDI series IT.NET.USER.ZS, sourced from the International Telecommunication Union. It is the percentage of individuals who used the internet from any location during the preceding three months (World Bank, 2026b). The measure captures adoption, not connection speed, price, reliability, institutional network capacity or scientists' behaviour. Because early values are right-skewed and the scale is bounded near 100, the analysis uses ln(1 + percentage) before lagging and standardisation. Fixed-broadband subscriptions per 100 people are considered only as an alternative proxy because subscriptions and individual use are distinct constructs.

Government effectiveness is the standard WGI estimate filtered as GOV_WGI_GE and WGI_EST. Higher values indicate better perceived public-service quality, civil-service quality, policy implementation and credibility. The analysis uses a single version of the 2025-revised series, whose historical estimates were recalculated to 1996; it does not mix the revision with archived WDI governance series (World Bank, 2025; Romano *et al.*, 2026). WGI is constructed from surveys and expert assessments, contains margins of uncertainty and should not be interpreted as an objective, science-specific administrative score.

The baseline controls capture development level, external economic integration, labour-market slack and settlement structure. GDP per capita is logged constant-2015-dollar income; trade openness is exports plus imports as a percentage of GDP; unemployment is the ILO modelled share of the labour force; and urban population is the urban share. These indicators are taken from WDI (World Bank, 2026c). Tertiary enrolment, R&D expenditure and researchers per million are added separately in extensions because conditional missingness is approximately 35, 55 and 62 per cent, respectively. They may also be channels through which institutions influence research, so their coefficients are not given a simple structural interpretation.

*3.3 Empirical specification*

The baseline two-way fixed-effects model is shown in equation (2), where *IU* is standardised lagged internet use, *GE* is standardised lagged government effectiveness, *M* is their product, *X* is the control vector, *F* combines economy and year fixed effects, and *u* is the residual.

$$SP_{it} = \beta_0 + \beta_1 IU_{i,t-1} + \beta_2 GE_{i,t-1} + \beta_3 M_{i,t-1} + \gamma' X_{i,t-1} + F_{it} + u_{it} \quad (2)$$

The interaction coefficient answers RQ1. A positive value is consistent with complementarity; a negative value is consistent with substitution. Because the focal variables are centred through z-standardisation, the main internet-use coefficient is its slope at average government effectiveness. The conditional marginal effect is reported using equation (3), with its standard error calculated from the full variance–covariance matrix.

$$\frac{\partial SP_{it}}{\partial IU_{it}} = \beta_1 + \beta_3 GE_{i,t-1} \quad (3)$$

*3.4 Estimation, inference and sensitivity design*

The primary estimator is ordinary least squares with economy and year fixed effects and heteroskedasticity-robust standard errors clustered by economy. A two-way economy-and-year clustered covariance estimator allows for additional common temporal dependence. Sensitivity analyses add economy-specific linear trends or region-by-year fixed effects, use two-year lags, omit 2020–2021, change the winsorisation cut-offs, substitute fixed-broadband subscriptions and estimate first differences. The last specification is deliberately treated as a demanding sensitivity check rather than a purely annual-difference model, because 9 of its 2,647 changes span two to six years owing to intermittent source observations.

Two further specifications probe the meaning of the interaction. First, a fixed-effects hybrid decomposition separates within-economy deviations in internet use and government effectiveness from each economy's long-run average governance context. The interaction between within-economy internet change and mean government effectiveness asks whether the same internet-use change has a different association in persistently stronger administrative settings; the within–within interaction asks whether contemporaneous institutional change amplifies it.

Second, population-exposure Poisson pseudo-maximum likelihood (PPML) estimates fractional publication counts with log population as exposure, economy and year effects, and economy-clustered sandwich standard errors. PPML handles zero counts and heteroskedasticity without the ln(1 + intensity) transformation.

Extended specifications add tertiary enrolment, R&D expenditure and researcher density separately, with and without economy-specific trends. Leave-one-region-out estimates assess the influence of regional composition. The robustness exercise is not read as a vote count based on significant rows. Instead, the sign, magnitude and confidence interval are compared across models, with explicit attention to the specifications in which the baseline result no longer holds.

*3.5 Data integrity and reproducibility*

The extraction workflow records the indicator codes, access date and WGI release fingerprint. The WGI wide file used in the analysis has SHA-256 hash 663b4b1fb9aaa78efedd896a0761127e0c6cebf87cf0e3a8bfb37adec6f5c961. Validation requires non-negative article counts and population, same-year population in the intensity denominator, country sorting before lagging, unique ISO3-year keys and exact WGI filters. Descriptive statistics, coefficient tables and plot data are generated from the same estimation sample. Reporting the endpoints and definitions allows researchers to freeze later releases and evaluate revision sensitivity.

**4. Results**

*4.1 Descriptive evidence*

Table II reports descriptive statistics for the common baseline sample. Publication intensity has a mean of 4.377 log points and substantial cross-economy dispersion. Lagged log internet use ranges from 0.336 to 4.599 after winsorisation, while lagged government effectiveness covers approximately −1.915 to 2.098. The broad ranges are useful for global comparison, but the regression coefficients are identified after economy and year effects rather than from these pooled level differences.

***Table II. Descriptive statistics for the baseline estimation sample***

| Variable | N | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| Publication intensity (log) | 2,811 | 4.377 | 2.092 | 0.217 | 7.687 |
| Internet use (log), t−1 | 2,811 | 3.387 | 1.110 | 0.336 | 4.599 |
| Government effectiveness, t−1 | 2,811 | 0.016 | 0.958 | −1.915 | 2.098 |
| GDP per capita (log), t−1 | 2,811 | 8.636 | 1.411 | 5.960 | 11.564 |
| Trade openness, t−1 | 2,811 | 85.905 | 48.367 | 25.241 | 350.897 |
| Unemployment, t−1 | 2,811 | 7.691 | 5.689 | 0.583 | 26.545 |
| Urban population, t−1 | 2,811 | 60.313 | 21.646 | 14.699 | 100.000 |

***Note:*** *Statistics use the same 1/99 winsorised, transformed and lagged variables as the baseline estimates before z-standardisation.*

Pooled Pearson correlations in Table III are high among publication intensity, income and government effectiveness, which is expected in global level data. The outcome correlates 0.765 with internet use and 0.841 with government effectiveness; GDP per capita correlates 0.846 with the outcome. These coefficients describe between- and within-economy variation together and are not estimates of the fixed-effects relationships. They reinforce the need for economy effects and for avoiding a causal reading of pooled national rankings.

***Table III. Pooled Pearson correlations***

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Publication intensity | 1.000 | | | | | | |
| 2. Internet use | .765 | 1.000 | | | | | |
| 3. Government effectiveness | .841 | .664 | 1.000 | | | | |
| 4. GDP per capita | .846 | .741 | .840 | 1.000 | | | |
| 5. Trade openness | .283 | .266 | .338 | .356 | 1.000 | | |
| 6. Unemployment | .072 | .108 | −.073 | .022 | .038 | 1.000 | |
| 7. Urban population | .652 | .652 | .564 | .776 | .229 | .151 | 1.000 |

***Note:*** *N = 2,811. The lower-triangular matrix is pooled; it should not be read as a within-economy fixed-effects correlation matrix.*

*4.2 Baseline fixed-effects estimates*

Table IV builds from the control model to the full interaction specification. Internet use enters positively in Column 2 (0.179, $p = 0.0016$). Government effectiveness is positive in Column 3 (0.199, $p = 0.017$), without materially changing the sign of internet use. In Column 4, internet use is 0.286 ($p < 0.001$), government effectiveness is 0.205 ($p = 0.011$) and their interaction is 0.096 ($p = 0.030$).

Incremental within $R^2$ rises from 0.113 in the control model to 0.165 in the full model. The baseline estimates are consistent with H1 and H2. For RQ1, the positive interaction initially favours complementarity, although its stability is assessed below.

***Table IV. Baseline economy and year fixed-effects estimates***

| Variable | (1) Controls | (2) + Internet | (3) + Government | (4) Interaction |
|---|---|---|---|---|
| Internet use | — | .179*** (.056) | .171*** (.055) | .286*** (.062) |
| Government effectiveness | — | — | .199** (.083) | .205** (.079) |
| Internet use × government | — | — | — | .096** (.044) |
| GDP per capita (log) | .819*** (.135) | .732*** (.136) | .628*** (.146) | .574*** (.141) |
| Trade openness | −.002* (.001) | −.001 (.001) | −.001 (.001) | −.001 (.001) |
| Unemployment | .026*** (.008) | .022*** (.007) | .024*** (.007) | .023*** (.008) |
| Urban population | .011 (.008) | .002 (.009) | .002 (.009) | .002 (.008) |
| Economy fixed effects | Yes | Yes | Yes | Yes |
| Year fixed effects | Yes | Yes | Yes | Yes |
| Observations | 2,811 | 2,811 | 2,811 | 2,811 |
| Economies | 164 | 164 | 164 | 164 |
| Incremental within $R^2$ | .113 | .140 | .152 | .165 |

***Note:*** *Dependent variable: ln(1 + winsorised S&E articles per million residents). Internet use and government effectiveness are z-standardised. All explanatory variables are lagged one year. Economy-clustered standard errors in parentheses. The reported $R^2$ is incremental relative to an economy-and-year fixed-effects-only model. ***$p < .01$; **$p < .05$; *$p < .10$.*

Because the interaction coefficient is not meaningful in isolation, Figure 2 reports the estimated conditional association between a one-standard-deviation increase in lagged log internet use and publication intensity over the 5th–95th percentile range of government effectiveness. At the 5th percentile ($z = -1.434$), the slope is 0.148 (95 per cent CI 0.027–0.269); at the median ($z = -0.160$), it is 0.270 (0.154–0.387); and at the 95th percentile ($z = 1.912$), it is 0.469 (0.217–0.721). On the log outcome scale these correspond approximately to 16, 31 and 60 per cent differences, respectively. The analytical Johnson–Neyman boundary is about $z = -1.624$, above which 97.2 per cent of baseline observations lie. These are conditional associations on the log scale, not estimated policy treatment effects.

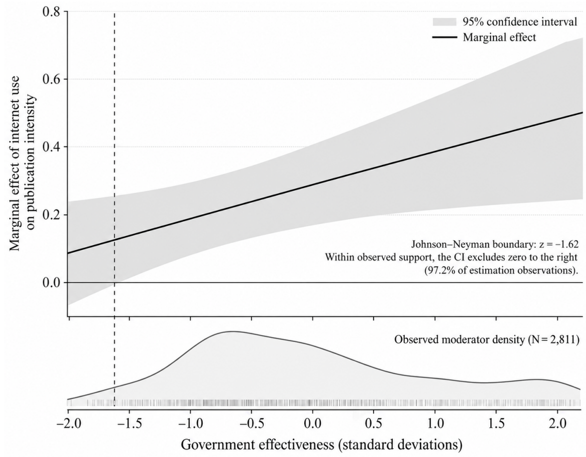


***Figure 2. Conditional association of internet use with publication intensity***

*Source: Authors' estimates from Table IV, Column 4. The band is the 95% confidence interval; the rug shows the observed distribution. The vertical reference marks the analytical Johnson–Neyman boundary ($z = -1.624$).*

*4.3 Robustness, alternative estimands and boundary conditions*

Figure 3 compares the interaction estimates across the core sensitivity set; Table V provides the corresponding coefficients and inference. The baseline interaction is unchanged under two-way clustering and remains positive with economy-specific trends (0.098, $p = 0.023$), two-year lags (0.094, $p = 0.031$), exclusion of 2020–2021 (0.091, $p = 0.038$) and 2.5/97.5 per cent winsorisation (0.107, $p = 0.014$). These specifications show that the estimate is not driven solely by the one-year lag, the acute pandemic observations or the treatment of distributional tails.

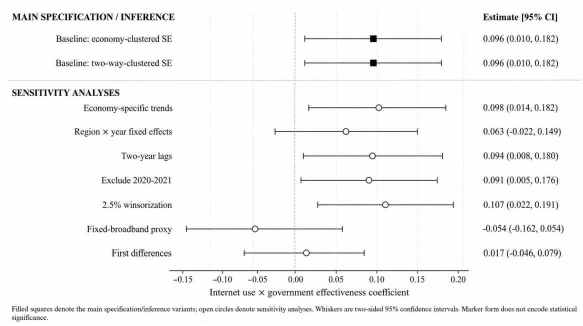


***Figure 3. Sensitivity of the internet use × government effectiveness coefficient***

*Source: Authors' estimates. Points are coefficients and lines are 95% confidence intervals. The visual grouping separates the baseline family from specifications that change common-shock controls, the digital proxy or the temporal estimand.*

Several specifications mark clear limits to the baseline result. Region-by-year fixed effects reduce the coefficient to 0.063 and render it imprecise ($p = 0.145$), suggesting that regional waves account for part of the association. Replacing population internet use with fixed-broadband subscriptions yields a negative, imprecise interaction (−0.054, $p = 0.325$), although fixed broadband itself remains positively associated with publication intensity. The differenced interaction is near zero (0.017, $p = 0.595$), showing that short-run joint changes do not reproduce the levels/trends relationship.

The hybrid decomposition helps locate this difference. A within-economy internet-use deviation is positively associated with publishing (0.161, $p < 0.001$). Its interaction with the economy's long-run average government effectiveness is positive but only marginally precise (0.057, $p = 0.071$), whereas the within-internet × within-government interaction is essentially zero (−0.005, $p = 0.678$). Taken literally, this pattern is more consistent with slowly moving institutional context than with immediate co-movement. In the population-exposure PPML model, internet use (0.453, $p < 0.001$) and government effectiveness (0.220, $p = 0.035$) remain positive, but the interaction is negative and imprecise (−0.063, $p = 0.392$). The interaction is therefore sensitive to whether publishing is represented as log intensity or as an exposed count.

***Table V. Robustness and estimand sensitivity of the conditioning relationship***

| Specification | Coefficient | SE | p | N | Economies | Incr. $R^2$ |
|---|---|---|---|---|---|---|
| Baseline TWFE | .0958 | .0437 | .030 | 2,811 | 164 | .165 |
| Economy + year clustered SE | .0958 | .0407 | .031 | 2,811 | 164 | .165 |
| Economy-specific trends | .0978 | .0425 | .023 | 2,811 | 164 | .614 |
| Region × year fixed effects | .0634 | .0433 | .145 | 2,811 | 164 | .232 |
| Two-year lags | .0940 | .0433 | .031 | 2,811 | 165 | .177 |
| Exclude 2020–2021 | .0905 | .0432 | .038 | 2,501 | 164 | .146 |
| 2.5/97.5 % winsorisation | .1066 | .0427 | .014 | 2,811 | 164 | .182 |
| Fixed-broadband proxy | −.0540 | .0548 | .325 | 2,737 | 164 | .175 |
| First differences | .0169 | .0317 | .595 | 2,647 | 164 | .002 |
| Hybrid: within internet × mean GE | .0569 | .0313 | .071 | 2,811 | 164 | — |
| Hybrid: within internet × within GE | −.0051 | .0122 | .678 | 2,811 | 164 | — |
| PPML count with population exposure | −.0633 | .0740 | .392 | 2,811 | 164 | — |

*Note: Except for the two-way-clustered row, standard errors are economy-clustered. Hybrid and PPML rows estimate related but differently scaled interactions; PPML uses fractional article counts with a population offset. GE = government effectiveness.*

*4.4 Extended research-resource controls and geographic stability*

Table VI adds research-resource controls separately to avoid the severe attrition produced by a joint complete-case specification. With tertiary enrolment, the interaction is positive in the level fixed-effects model and the trend model. With R&D expenditure or researcher density, the interaction is not significant in the level specification but becomes positive under economy-specific trends. Because the samples shrink to 97 and 89 economies and the resource variables may be mediators, these results do not overturn the functional-form caution in Table V.

***Table VI. Extended innovation-resource controls***

| Added variable | Specification | Interaction | Added-variable coef. | N | Economies | Incr. $R^2$ |
|---|---|---|---|---|---|---|
| Tertiary enrolment | Level FE | .0932** (.0442) | .00587*** (.00183) | 2,009 | 137 | .154 |
| Tertiary | + econo | .1183** | .00156 | 2,00 | 137 | .591 |

| Added variable | Specification | Interaction | Added-variable coef. | N | Economies | Incr. $R^2$ |
|---|---|---|---|---|---|---|
| enrolment | my trends | (.0483) | (.00206) | 9 | | |
| R&D expenditure | Level FE | −.0138 (.0578) | −.0091 (.0717) | 1,470 | 97 | .179 |
| R&D expenditure | + economy trends | .1516** (.0616) | .0725 (.0639) | 1,470 | 97 | .602 |
| Researchers per million | Level FE | .0076 (.0498) | −.000065** (.000031) | 1,244 | 89 | .386 |
| Researchers per million | + economy trends | .2030*** (.0720) | .000062** (.000029) | 1,244 | 89 | .804 |

***Note:*** *Each resource is estimated in a separate restricted sample, and focal variables are re-standardised within that sample. All models include baseline controls, economy and year fixed effects. Standard errors are economy-clustered. ***p < .01; **p < .05.*

Leave-one-region-out coefficients remain positive, ranging from 0.066 to 0.140, but precision varies. Excluding East Asia and the Pacific or Europe and Central Asia leaves only 10 per cent-level evidence. Most importantly, excluding Sub-Saharan Africa lowers the interaction to 0.066 with p = 0.311. No single region reverses the estimate, although its precision clearly depends on regional composition.

*4.5 Assessment of the hypotheses and research question*

The estimates are most consistent with H1: the internet-use coefficient is positive in the baseline sequence, hybrid model and PPML count model. They are also consistent with H2 in the baseline and PPML models, although the breadth of the WGI construct precludes a science-administration interpretation. RQ1 receives a conditional answer. The positive baseline interaction and several lag and trend checks favour complementarity, but region-by-year effects, first differences, fixed broadband, PPML and the weak hybrid cross-level estimate do not provide a stable directional result. Direct associations are considerably more consistent than the conditioning relationship.

## 5. Discussion

*5.1 Interpreting the direct associations*

Internet use provides the clearest empirical signal in the study. Its positive association with publication intensity fits the view of digital networks as general-purpose knowledge infrastructure, but it should not be read as papers produced by marginal new users. Higher population use is associated with easier access to information, communication services and online learning, and with a larger set of organisations that can be reached digitally. Such conditions can reduce friction around universities and laboratories even though the indicator does not describe researchers. This pattern extends earlier evidence on digitally enabled collaboration (Wernsdorf *et al.*, 2022) and education-conditioned research performance (Uyar *et al.*, 2023) in a broader national publishing context.

Government effectiveness has a separate positive association with publishing, in line with work linking institutional quality to innovation (Danta and Rath, 2024) and administrative effectiveness to national innovation systems (Singh *et al.*, 2025). For managers, the plausible connection is reliability. Universities and laboratories plan within administrative systems that shape the predictability of funding, procurement, mobility and public services. The WGI coefficient cannot identify any one of these channels; it shows only that a broad governance measure remains related to publishing after persistent economy characteristics and common annual shocks are absorbed.

*5.2 Why the complementarity result is conditional*

The moderation evidence is more nuanced than the direct associations. In the baseline log-intensity model, the same standardised difference in internet use is associated with a larger publishing difference at higher levels of government effectiveness. One possible explanation is that reliable administration helps universities benefit from wider internet participation through more stable funding, services and coordination. The hybrid estimates, however, place the conditioning role in persistent governance context rather than short-run joint improvement. This interpretation is plausible, but persistent context is difficult to separate from other durable features of national research systems.

The conclusion changes with the outcome model. The interaction is positive in the log1p per-capita model but negative and imprecise in PPML with population exposure. Log intensity reduces the leverage of the largest publishing systems and gives more attention to proportional differences among smaller producers. PPML models expected publication counts directly and retains zeroes without an additive constant. Neither is the universally correct estimand. Their disagreement means that the statement ‘government effectiveness amplifies internet use’ is not scale-free. The policy question must first specify whether the relevant outcome is proportional publishing intensity or expected aggregate output.

Read against Pudasaini and Kornwattanakit (2026), the estimates show partial convergence rather than a simple contradiction. Their patent models combine positive additive associations with diminishing marginal returns to connectivity at higher institutional strength, while their grant results are weaker and more context-dependent. Here, the positive log-intensity interaction implies amplification, whereas the negative but imprecise PPML interaction is directionally closer to their diminishing-return pattern. This comparison does not establish different mechanisms for publications and patents. It suggests that digital–institutional relationships may depend on the innovation stage, institutional construct and outcome estimand. Cumulative research should connect publications, patents and commercialisation within the same staged model.

*5.3 Theoretical contributions*

Conceptually, the article distinguishes a broad digital input from the organisational capacities that turn access into codified knowledge. This distinction speaks to efficiency research showing that resource-rich systems may still convert inputs poorly (Erdin and Çağlar, 2023; Anouze *et al.*, 2024). The direct internet-use association is more stable across outcome models than its interaction with governance, suggesting that the access–output link may be more general than any single administrative complement.

For public-management research, government effectiveness is specified as a system-level governance context rather than folded into a broad institutional index. This provides a more explicit bridge to innovation-system scholarship. Public organisations pursue different digital innovation strategies and vary in their ability to enhance, anticipate, adapt and persist (Guenduez *et al.*, 2025). At national scale, publication outcomes may accordingly depend less on the formal presence of digital programmes than on the administrative capacity to execute and coordinate them.

Methodologically, variation across robustness tests is used to refine the claim rather than to select a preferred significant model. Alternative temporal controls, a proxy change, decomposition and an exposed-count model distinguish three propositions that are often collapsed: internet use is positively related to publishing; government effectiveness is positively related to publishing; and government effectiveness amplifies the internet-use association. The first two receive substantially more consistent support than the third. Keeping that hierarchy visible offers a firmer basis for cumulative research.

*5.4 Implications for research-system managers and policymakers*

For universities, public laboratories and research councils, the results do not support evaluating connectivity in isolation. Connectivity can expand faster than interoperable research services, procurement competence, grant administration, data governance and staff skill, leaving a weak link between access and output. Administrative reform without broad digital inclusion creates the opposite risk: capable services that remain concentrated among already connected organisations. Managers should therefore diagnose the bottleneck between access, coordination and publication rather than maximise two dashboard scores in parallel.

Sequencing will differ by context. Where internet use remains low, affordability, reliability and digital literacy are likely to be immediate constraints. Where connectivity is already widespread, attention may shift to research-data infrastructure, cross-institutional authentication, open-science repositories, high-performance computing and stable administrative rules. Process indicators such as grant-cycle time, procurement delay, repository uptake, inter-university collaboration and network reliability can reveal these bottlenecks more directly than WGI scores or population-use rates. These are priorities for evaluation, not effects identified by the economy-level estimates.

Evaluation should match the stated policy objective. A programme may affect aggregate publications, per-capita intensity, collaboration quality or inclusion without moving all four. The disagreement between the log-intensity and PPML interactions is a warning against selecting an outcome transformation after seeing the results. Prospective analysis plans, lag windows tied to research cycles and the reporting of null sensitivity tests would make programme evidence more informative and easier to compare.

*5.5 Limitations and directions for research*

The design is observational. A one-year lag and two-way fixed effects do not establish causality. Strong research systems can stimulate digital adoption, attract talent and improve perceptions of government performance. Time-varying omitted factors—including academic freedom, electricity reliability, international funding, English-language orientation and major science reforms—may influence all three focal measures. Economy-specific trends and region-by-year effects reduce but cannot eliminate these concerns. Stronger designs could exploit well-defined connectivity roll-outs, administrative reforms or plausibly exogenous disruptions with transparent treatment timing and pre-trend diagnostics.

Measurement sets a second boundary. Internet use is a population adoption rate rather than research connectivity; government effectiveness is a perception-based general governance estimate; and the outcome is a Scopus-covered, gap-filled science-and-engineering count rather than research quality. Country attribution in international collaboration creates network spillovers, so one country's digital environment may affect another country's fractional output. Subsequent research should combine author-level collaboration networks, field-normalised citation impact, open-access status, connection quality, affordability and research-organisation surveys. Scientific fitness and disciplinary diversification measures offer promising complements to counts (Patelli *et al.*, 2023).

Sample composition also matters. The panel is an unbalanced complete-case sample; the R&D and researcher extensions lose many lower-capacity observations, and excluding Sub-Saharan Africa materially reduces interaction precision. Because missingness is concentrated in lower-capacity settings, the estimates may not generalise to them. Future work should model inclusion explicitly, compare observed and excluded economies, and distinguish data absence from true zero activity. Regional designs may be more informative than ever larger global panels when measurement systems differ.

The linear interaction may also conceal saturation. Internet adoption approaches 100 per cent in many economies, while government effectiveness changes slowly and includes measurement uncertainty. Flexible splines, nonlinear varying-coefficient models and errors-in-variables approaches should test whether conditioning is concentrated in particular support regions. Future studies should pre-specify three- to five-year distributed lags that match grant and publication cycles, and compare publications with patents, doctoral training and public-value outcomes.

The organisational mechanisms remain unobserved. Search, coordination, resource allocation and credible implementation may connect the focal conditions to publishing, but the panel cannot demonstrate those channels. Mixed-method comparative research could pair cross-country estimates with process tracing in matched economies. Organisational data on grant administration, digital research services and inter-agency coordination could test whether the association operates through funding execution, service maintenance, inter-agency coordination or another institutional channel.

## 6. Conclusion

In this panel of 164 economies from 2006 to 2023, higher internet use and government effectiveness are each associated with greater science-and-engineering publication intensity. Their interaction is positive in the log-intensity model and remains positive with alternative lags, economy-specific trends and winsorisation thresholds. It weakens or changes sign, however, with region-by-year effects, first differences, fixed broadband and population-offset PPML. Evidence that government effectiveness strengthens the internet-use–publishing association is therefore conditional on the model and outcome scale.

The estimates do not identify causal policy effects. They support joint evaluation of connectivity and administrative reform, while leaving open which specific services or routines account for the observed associations. Future research should link national indicators to grant execution, digital research services, collaboration networks and field-normalised outputs to determine when administrative capacity complements—or substitutes for—digital participation in scientific publishing.

## Declarations

**Funding –** The authors received no specific grant from any funding agency in the public, commercial or not-for-profit sectors for this study.

**Conflict of interest –** The authors declare no conflict of interest.

**Ethics –** The study uses only publicly available aggregate economy-level data and does not involve human participants or identifiable personal data.

**Data availability –** All source data are publicly available from the World Bank WDI API and the WGI Data360 repository. Indicator codes, release filters, extraction date and the WGI file hash are reported in Section 3.

**Author contributions –** Zile Fan and Chandra Mohan Vasudeva Panicker contributed to conceptualisation, methodology, interpretation and manuscript development. Both authors approved the submitted version.

## References

Abramo, G. and D'Angelo, C.A. (2024), "The scientific standing of nations and its relationship with economic competitiveness", *PLOS ONE*, Vol. 19 No. 6, article e0304299, doi: https://doi.org/10.1371/journal.pone.0304299.

Afawubo, K. and Noglo, Y.A. (2022), "ICT and entrepreneurship: a comparative analysis of developing, emerging and developed countries", *Technological Forecasting and Social Change*, Vol. 175, article 121312, doi: https://doi.org/10.1016/j.techfore.2021.121312.

Anouze, A.L., Al Khalifa, M.M. and Al-Jayyousi, O.R. (2024), "Reevaluating national innovation systems: an index based on dynamic-network data envelopment analysis", *Socio-Economic Planning Sciences*, Vol. 95, article 102003, doi: https://doi.org/10.1016/j.seps.2024.102003.

Dabbous, A., Barakat, K.A. and Kraus, S. (2023), "The impact of digitalization on entrepreneurial activity and sustainable competitiveness: a panel data analysis", *Technology in Society*, Vol. 73, article 102224, doi: https://doi.org/10.1016/j.techsoc.2023.102224.

Danta, S. and Rath, B.N. (2024), "Do institutional quality and human capital matter for innovation in case of Asian region?", *Innovation and Green Development*, Vol. 3 No. 3, article 100141, doi: https://doi.org/10.1016/j.igd.2024.100141.

Duarte, M.P. and Carvalho, F.M.P.O. (2024), "How digital transformation shapes European Union countries' national systems of innovation: a configurational moderation approach", *Journal of Innovation & Knowledge*, Vol. 9 No. 4, article 100578, doi: https://doi.org/10.1016/j.jik.2024.100578.

Erdin, C. and Çağlar, M. (2023), "National innovation efficiency: a DEA-based measurement of OECD countries", *International Journal of Innovation Science*, Vol. 15 No. 3, pp. 427-456, doi: https://doi.org/10.1108/IJIS-07-2021-0118.

Erzurumlu, S.S., Erzurumlu, Y.O. and Yoon, Y. (2022), "National innovation systems and dynamic impact of institutional structures on national innovation capability: a configurational approach with the OKID method", *Technovation*, Vol. 114, article 102552, doi:

https://doi.org/10.1016/j.technovation.2022.102552.

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, Pinter, London.

Furman, J.L., Porter, M.E. and Stern, S. (2002), “The determinants of national innovative capacity”, *Research Policy*, Vol. 31 No. 6, pp. 899-933, doi: https://doi.org/10.1016/S0048-7333(01)00152-4.

Guenduez, A.A., Demircioglu, M.A., Mueller, E.M. and Cinar, E. (2025), “Digital innovation strategies in the public sector”, *Research Policy*, Vol. 54 No. 8, article 105274, doi: https://doi.org/10.1016/j.respol.2025.105274.

Huang, Y., Li, S., Xiang, X. and Huang, L. (2024), “Analyzing the configuration of the national innovation system for innovation capability: evidence from Global Innovation Index reports”, *Humanities and Social Sciences Communications*, Vol. 11, article 1266, doi: https://doi.org/10.1057/s41599-024-03792-x.

Lancho-Barrantes, B.S., Ceballos-Cancino, H.G. and Cantu-Ortiz, F.J. (2021), “Comparing the efficiency of countries to assimilate and apply research investment”, *Quality & Quantity*, Vol. 55 No. 4, pp. 1347-1369, doi: https://doi.org/10.1007/s11135-020-01063-w.

Lee, K., Lee, J. and Lee, J. (2021), “Variety of national innovation systems (NIS) and alternative pathways to growth beyond the middle-income stage: balanced, imbalanced, catching-up, and trapped NIS”, *World Development*, Vol. 144, article 105472, doi: https://doi.org/10.1016/j.worlddev.2021.105472.

Lundvall, B.-Å. (Ed.) (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter, London.

Ndicu, S., Ngui, D. and Barasa, L. (2024), “Technological catch-up, innovation, and productivity analysis of national innovation systems in developing countries in Africa 2010–2018”, *Journal of the Knowledge Economy*, Vol. 15 No. 2, pp. 7941-7967, doi: https://doi.org/10.1007/s13132-023-01327-4.

Nelson, R.R. (Ed.) (1993), *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York, NY.

Patelli, A., Napolitano, L., Cimini, G. and Gabrielli, A. (2023), “Geography of science: competitiveness and inequality”, *Journal of Informetrics*, Vol. 17 No. 1, article 101357, doi: https://doi.org/10.1016/j.joi.2022.101357.

Pinedo-López, J., Baena-Navarro, R., Carriazo-Regino, Y., Torres-Hoyos, F. and Nieves-Garces, D. (2025), “Science, technology, and innovation policy and regional scientific production in Colombia: a methodological framework to address asymmetries in developing countries”, *Journal of Innovation and Entrepreneurship*, Vol. 14, article 89, doi: https://doi.org/10.1186/s13731-025-00562-0.

Prokop, V., Hajek, P. and Stejskal, J. (2021), “Configuration paths to efficient national innovation ecosystems”, *Technological Forecasting and Social Change*, Vol. 168, article 120787, doi: https://doi.org/10.1016/j.techfore.2021.120787.

Pudasaini, S. and Kornwattanakit, S. (2026), “Digital connectivity, institutional strength and innovation governance: evidence from 65 countries, 2010–2023”, *Digital Policy, Regulation and Governance*, ahead-of-print, pp. 1-30, doi: https://doi.org/10.1108/DPRG-11-2025-0429.

Romano, T., Loayza, N.V., Jiang, C.N., Jain, A. and Boyce, T. (2026), “The Worldwide Governance Indicators: revised methodology for measuring governance using perception data”, *World Bank Reproducibility Repository*, reference RR_WLD_2026_558, doi: https://doi.org/10.60572/xw15-k486.

Singh, S., Dhir, S., Mukunda Das, V. and Sharma, A. (2025), “Analyzing institutional factors influencing the national innovation system”, *Journal of Science and Technology Policy Management*, Vol. 16 No. 8, pp. 1445-1466, doi: https://doi.org/10.1108/JSTPM-05-2023-0063.

Uyar, A., Nimer, K. and Kuzey, C. (2023), “Education quality, internet access in schools, and research performance in management and accounting domains: a cross-country investigation”, *Scientometrics*, Vol. 128 No. 10, pp. 5441-5475, doi: https://doi.org/10.1007/s11192-023-04813-3.

Wen, J., Deng, P., Zhang, Q. and Chang, C.-P. (2021), “Is higher government efficiency bringing about higher innovation?”, *Technological and Economic Development of Economy*, Vol. 27 No. 3, pp. 626-655, doi: https://doi.org/10.3846/tede.2021.14269.

Wernsdorf, K., Nagler, M. and Watzinger, M. (2022), “ICT, collaboration, and innovation: evidence from BITNET”, *Journal of Public Economics*, Vol. 211, article 104678, doi: https://doi.org/10.1016/j.jpubeco.2022.104678.

World Bank (2025), *Worldwide Governance Indicators: 2025 Revision*, World Bank Data Catalog, available at: https://datacatalog.worldbank.org/search/dataset/0038026/worldwide-governance-indicators (accessed 16 August 2026).

World Bank (2026a), *Scientific and Technical Journal Articles (IP.JRN.ARTC.SC)*, World Development Indicators, available at: https://data.worldbank.org/indicator/IP.JRN.ARTC.SC (accessed 16 August 2026).

World Bank (2026b), *Individuals Using the Internet (% of Population) (IT.NET.USER.ZS)*, World Development Indicators, available at: https://data.worldbank.org/indicator/IT.NET.USER.ZS (accessed 16 August 2026).

World Bank (2026c), *World Development Indicators*, World Bank DataBank, available at: https://databank.worldbank.org/source/world-development-indicators (accessed 16 August 2026).

Yang, C., Gu, M. and Albitar, K. (2024), "Government in the digital age: exploring the impact of digital transformation on governmental efficiency", *Technological Forecasting and Social Change*, Vol. 208, article 123722, doi: https://doi.org/10.1016/j.techfore.2024.123722.

Zabala-Iturriagagoitia, J.M., Aparicio, J., Ortiz, L., Carayannis, E.G. and Grigoroudis, E. (2021), "The productivity of national innovation systems in Europe: catching up or falling behind?", *Technovation*, Vol. 102, article 102215, doi: https://doi.org/10.1016/j.technovation.2020.102215.

Zhang, J., van Gorp, D. and Kievit, H. (2023), "Digital technology and national entrepreneurship: an ecosystem perspective", *The Journal of Technology Transfer*, Vol. 48 No. 3, pp. 1077-1105, doi: https://doi.org/10.1007/s10961-022-09934-0.

Zhang, X. and Murad, M. (2026), "When collaboration meets responsibility: responsible innovation as a pathway linking collaborative and responsible entrepreneurship to venture performance", *Corporate Social Responsibility and Environmental Management*, ahead-of-print, pp. 1-18, doi: https://doi.org/10.1002/csr.70764.

Zou, Q., Mao, Z., Yan, R., Liu, S. and Duan, Z. (2023), "Vision and reality of e-government for governance improvement: evidence from global cross-country panel data", *Technological Forecasting and Social Change*, Vol. 194, article 122667, doi: https://doi.org/10.1016/j.techfore.2023.122667.