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# Can Economies Leapfrog to Digital Success?

## Evidence from Global E-commerce Development Pathways

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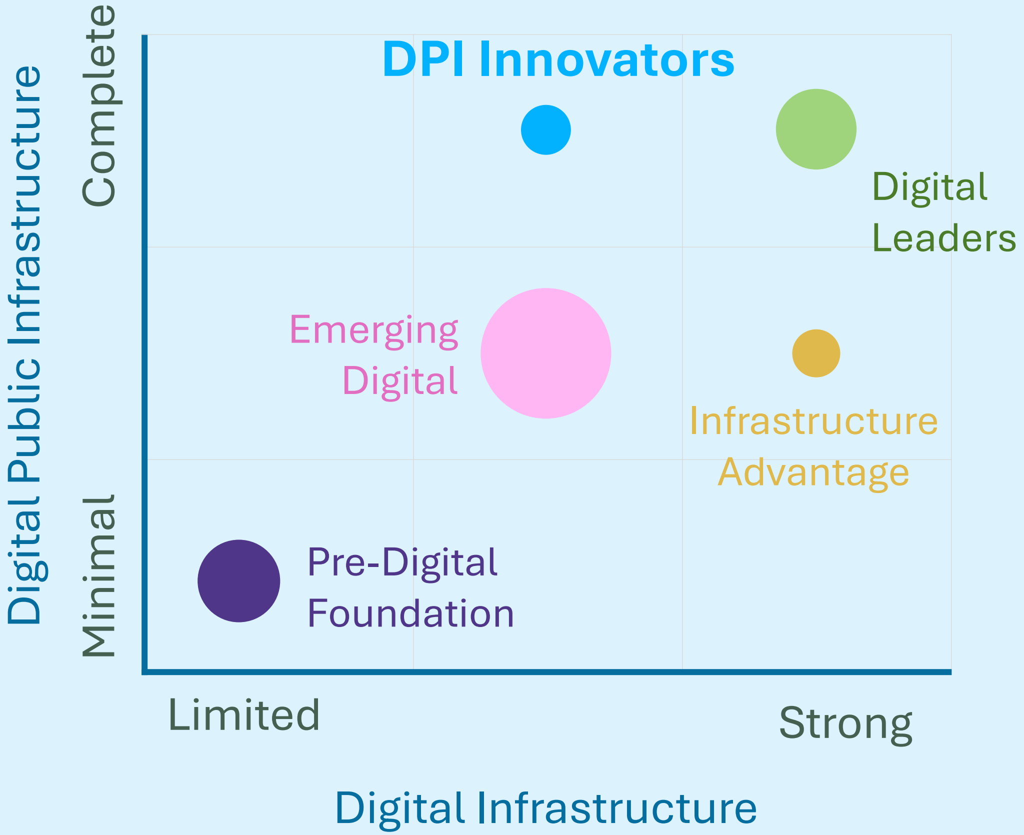
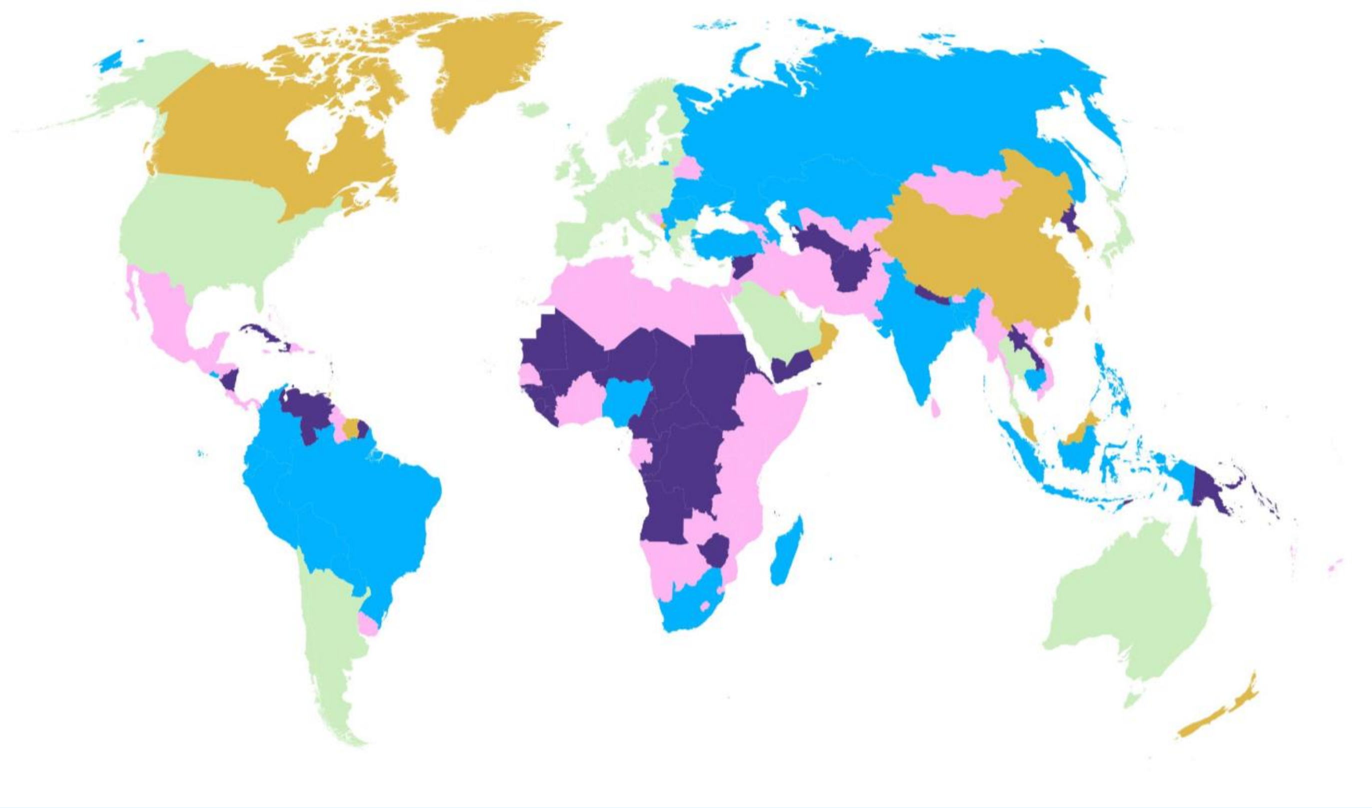
# Digital Development Map: Multiple Paths to Success

## How do digital infrastructure and Digital Public Infrastructure (DPI) interact to determine e-commerce capabilities?



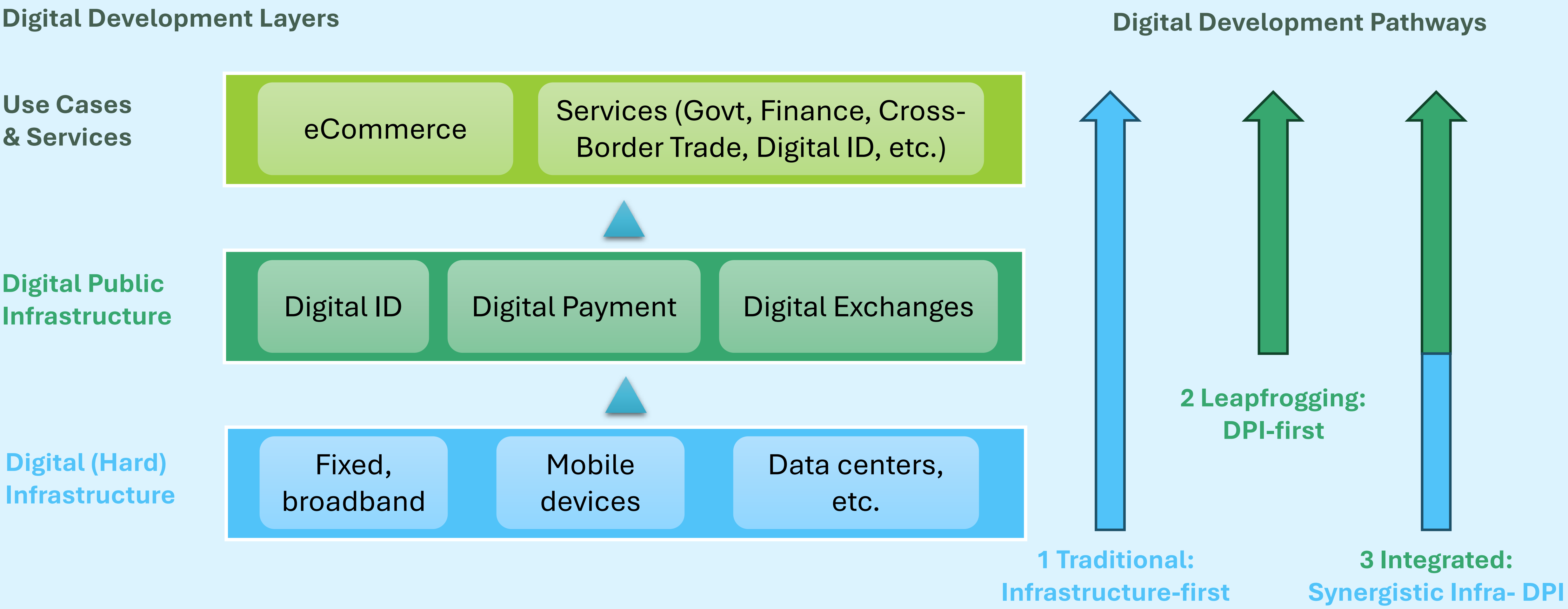

*Note: Radius of circle corresponds to relative size of the group.*

**Digital Infrastructure X Digital Public Infrastructure**



# Digital Development Theories

This research tested three digital development theories (infrastructure-first, DPI-enabled leapfrogging, and integrated synergy) using causal identification methods across 149 economies.



# Research Approach

## Data and Sources

ITU: Digital Infrastructure (16 indicators, 194 countries)

UCL DPIMap.Org: DPI Quality (3 systems, 205 countries)

Statista: eCommerce Revenue and Penetration (149 countries)

Time Period: 2023-2025 (cross-sectional analysis)

## Research Questions

How do digital infrastructure and Digital Public Infrastructure (DPI) systems independently and jointly influence e-commerce outcomes?

What evidence exists for leapfrogging through DPI-enabled pathways?

Which investment combinations optimize digital trade readiness?

What strategic approaches fit different country contexts?

## Methodology

Tercile-based pathway classification (204 countries)

Stepwise regression analysis

Instrumental variables estimation using income group averages

ANOVA pathway performance analysis

Complete data analysis: 149 countries

# Sample Characteristics and Variable Distributions

Analysis covers 149 economies with substantial variation across e-commerce outcomes, DPI quality, and infrastructure indicators.

| Variable | Mean | Std. Dev. | Min | Max | N |
|---|---|---|---|---|---|
| **E-commerce Outcomes** | | | | | |
| Revenue ($million, 2023) | 21.68 | 115.52 | 0.05 | 1,027.42 | 149 |
| User penetration (%, 2023) | 28.57 | 19.81 | 3.70 | 81.30 | 149 |
| **DPI Quality Indices** | | | | | |
| DPI overall simple | 0.50 | 0.31 | 0.00 | 1.00 | 204 |
| Digital ID quality | 0.46 | 0.34 | 0.00 | 1.00 | 204 |
| Payment quality | 0.49 | 0.35 | 0.00 | 1.00 | 204 |
| Data exchange quality | 0.55 | 0.39 | 0.00 | 1.00 | 204 |
| **Selected Infrastructure Indicators** | | | | | |
| Mobile broadband subscribers (%) | 84.92 | 51.67 | 0.00 | 421.39 | 204 |
| Fixed broadband subscribers (%) | 16.90 | 15.80 | 0.00 | 56.00 | 204 |
| Household internet (%) | 68.89 | 27.27 | 0.00 | 100.00 | 204 |
| 4G coverage (%) | 83.11 | 26.30 | 0.00 | 100.00 | 204 |

# Testing Infrastructure vs DPI Pathways

**RQ1: Pathway Identification. How do digital infrastructure and Digital Public Infrastructure (DPI) systems independently and jointly influence e-commerce outcomes?**

- Infrastructure alone explains 53% of e-commerce variance, DPI alone 26%, combined models 54%—suggesting infrastructure dominates with DPI providing marginal additional explanatory power
  - International bandwidth emerges as strongest infrastructure predictor
  - 4G coverage positively associated, 3G coverage shows negative coefficients
  - DPI remains significant in combined model, suggesting independent effects
  - Interaction terms positive, hinting at synergies

| | Model 1 ln (Revenue) | Model 2 ln (Revenue) | Model 3 ln (Revenue) | Model 4 ln (Revenue) |
|---|---|---|---|---|
| International bandwidth usage (Mb/s) | 12.948*** | | 12.925*** | |
| | (2.512) | | (2.806) | |
| Active mobile broadband subscriptions | 5.235* | | 3.314 | |
| | (2.139) | | (1.864) | |
| Mobile cellular subscriptions | -2.950 | | | |
| | (1.592) | | | |
| Fixed broadband subscriptions per 100 people | 2.621*** | | 2.219*** | |
| | (0.541) | | (0.580) | |
| DPI Overall (Simple index) | | 4.472*** | 1.757* | 5.401 |
| | | (0.522) | (0.687) | (2.757) |
| 2G Coverage (%) | | | -2.098* | |
| | | | (0.869) | |
| 3G Coverage (%) | -2.381* | | -2.413* | |
| | (1.083) | | (0.997) | |
| 4G Coverage (%) | 2.548** | | 2.182* | |
| | (0.800) | | (0.854) | |
| DPI Overall (Simple index) X Active mobile broadband subscriptions | | | | 5.493* |
| | | | | (2.682) |
| DPI Overall (Simple index) X Fixed broadband subscriptions per 100 people | | | | 3.430*** |
| | | | | (0.866) |
| DPI Overall (Simple index) X 2G Coverage (%) | | | | -5.581* |
| | | | | (2.720) |
| DPI Overall (Simple index) X International bandwidth usage (Mb/s) | | | | 17.17*** |
| | | | | (4.505) |
| N | 149 | 149 | 149 | 149 |
| Adjusted R-squared | 0.527 | 0.263 | 0.537 | 0.488 |

*Standard errors in parentheses. ***p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05*

# Addressing Endogeneity and Reverse Causality

Instrumental variables using income group averages address endogeneity and reverse causality.

**Individual 2SLS Results: Dependent Variable = ln(E-commerce Revenue)**

| Instrumented Variable | DPI Quality | | 4G Coverage | | 3G Coverage | | Fixed Broadband | | Mobile Broadband | | Intl Bandwidth (OLS-Exogenous) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st stage | 2nd stage | 1st stage | 2nd stage | 1st stage | 2nd stage | 1st stage | 2nd stage | 1st stage | 2nd stage | |
| Income group (instrument) | 0.992***<br>(0.120) | | 0.836***<br>(0.130) | | 0.737***<br>(0.165) | | 1.011***<br>(0.058) | | 1.083***<br>(0.099) | | |
| DPI Quality (instrumented) | | 7.150***<br>(1.093) | | | | | | | | | |
| 4G Coverage (instrumented) | | | | 7.697***<br>(1.351) | | | | | | | |
| 3G Coverage (instrumented) | | | | | | 17.137***<br>(4.078) | | | | | |
| Fixed Broadband (instrumented) | | | | | | | | 5.355***<br>(0.637) | | | |
| Mobile Broadband (instrumented( | | | | | | | | | | 14.644***<br>(1.969) | |
| Intl Bandwitdh (normal) | 0.536***<br>(0.202) | 11.702***<br>(4.380) | 0.405***<br>(0.093) | 11.869***<br>(3.426) | 0.214***<br>(0.055) | 11.386***<br>(3.315) | 0.311***<br>(0.287) | 14.221***<br>(0.184) | 0.248**<br>(0.184) | 11.594***<br>(2.354) | 12.900***<br>(2.260) |
| Observations | 149 | 149 | 149 | 149 | 149 | 149 | 149 | 149 | 149 | 149 | 149 |
| F-statistics | 70.07 | | 41.60 | | 19.98 | | 308.09 | | 119.24 | | |
| Adjusted R-squared | 0.282 | 0.232 | 0.428 | 0.282 | 0.265 | 0.000 | 0.663 | 0.491 | 0.430 | 0.336 | 0.527 |

*Standard errors in parentheses. ***p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05*

# Addressing Endogeneity and Reverse Causality

**2SLS reveals causal effects are larger than OLS estimates, wherein countries expand infrastructure in response to e-commerce success severely biasing correlational analysis.**

- OLS captured countries transitioning from 3G to 4G as e-commerce grew, not the true causal effect of 3G infrastructure
- Countries expand mobile networks in response to digital economic growth, masking true causal impact
- Institutional digital investments also show responsive bias of success inducing investments

### Infrastructure vs DPI Pathways: OLS and IV Results

| Variable | Coefficients | | F-stat (IV) |
|---|---|---|---|
| | OLS | IV | |
| International bandwidth | 12.950*** (2.512) | 12.900*** (2.260) | - |
| Active mobile broadband subscriptions | 5.235* (2.139) | 14.644*** (1.969) | 119.24 |
| Fixed broadband subscriptions per 100 people | 2.621*** (0.541) | 5.355*** (0.637) | 308.09 |
| 4G Coverage | 2.548** (0.800) | 7.697*** (1.351) | 41.60 |
| 3G Coverage | -2.381* (1.083) | 17.137*** (4.078) | 19.98 |
| DPI Overall Quality | 4.472*** (0.522) | 7.150*** (1.093) | 70.07 |

*Standard errors in parentheses. ***p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05*

# Pathways of Digital Economic Performance

**RQ2: Alternative Pathways. What evidence exists for alternative development pathways that enable countries to achieve digital capabilities despite infrastructure constraints?**

- Infrastructure Advantage and DPI Innovator countries show statistically equivalent e-commerce revenues validating that different approaches achieve similar outcomes.

**Digital Development Pathway Performance Analysis (ANOVA)**

| | ln (Revenue) | User Penetration (%) |
|---|---|---|
| Digital Leaders | 0.736 | 25.786*** |
| | (0.426) | (3.687) |
| Infrastructure Advantage | -0.023 | 13.850** |
| | (0.837) | (5.866) |
| Emerging Digital | -1.631*** | -6.901* |
| | (0.372) | (3.115) |
| Pre-Digital Foundations | -2.45*** | -15.359*** |
| | (0.380) | (2.816) |
| N | 149 | 149 |
| Adjusted R-squared | 0.351 | 0.580 |
| F-statistic | 19.45*** | 49.80*** |

****p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05. DPI Innovators serve as the reference category (omitted). Revenue coefficients represent log differences relative to DPI Innovators. User penetration coefficients represent percentage point differences relative to DPI Innovators.*

# DPI Enables Alternative Development Paths

**RQ2: Leapfrogging validated (conditionally) with DPI Innovators demonstrating that complete digital systems generate substantial returns comparable to infrastructure investments**

1. Equivalent causal magnitude: DPI Quality (7.150***)≈ 4G coverage (7.697***)
2. Infrastructure vs. DPI pathways statistically similar (-0.023 coefficient)
3. 26 countries demonstrating this patter n

**Individual 2SLS Results: Dependent Variable = ln(E-commerce Revenue)**

| Instrumented Variable | DPI Quality | | 4G Coverage | |
|---|---|---|---|---|
| | 1st stage | 2nd stage | 1st stage | 2nd stage |
| Income group (instrument) | 0.992*** (0.120) | | 0.836*** (0.130) | |
| DPI Quality (instrumented) | | 7.150*** (1.093) | | |
| 4G Coverage (instrumented) | | | | 7.697*** (1.351) |
| Intl Bandwitdh (normal) | 0.536*** (0.202) | 11.702*** (4.380) | 0.405*** (0.093) | 11.869*** (3.426) |
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*Standard errors in parentheses. ***p ≤ 0.001, **p ≤ 0.01, *p ≤ 0.05*

# Regional Pathway Concentrations

**Regional concentrations create complementary capabilities. Europe leads in complete systems (Digital Leaders), Asia-Pacific shows pathway diversity, Africa represents largest development opportunity (Pre-Digital).**

### Asia Pacific

- Diversify innovations

### Africa

- Opportunity to develop market

### Latin America

- South-south cooperation leaders

### Europe

- Cross-border integration anchors

## Regional Integration Opportunities:

- Digital Leaders + Infrastructure Advantage: Provide regional connectivity backbones
- DPI Innovators: Contribute system design expertise and implementation models
- Emerging Digital: Serve as regional integration pilots and bridges
- Pre-Digital Foundation: Access regional systems while building domestic capabilities

# Investment Optimization by Pathway

**RQ3: Investment Optimization. Which combinations of digital investments prepare countries for participation in digital trade?**

Pathway-specific strategies optimize returns with Infrastructure Advantage countries represent highest-return opportunities through DPI completion, while DPI Innovators should scale regionally.

1. Infrastructure Advantage: Fast-track DPI → unlock untapped potential
2. DPI Innovators: Scale innovations regionally → South-South knowledge transfer
3. Digital Leaders: Cross-border interoperability → regional integration anchors
4. Emerging Digital: Balanced sequencing → avoid development stagnation
5. Pre-Digital: Mobile-first + targeted DPI → early returns despite constraints

# Strategic Implementation Approaches

## RQ4: Strategic Implementation. What approaches should guide digital development across different country contexts and starting conditions?

| Starting Condition | Recommended Pathway | Justification |
|---|---|---|
| Low infrastructure, low capital | DPI-First | Efficiency focus (with moderate investment) |
| Low infrastructure, high capital | Parallel Development | Accelerate both simultaneously |
| High infrastructure, incomplete DPI | DPI Completion | Unlock existing user base (Infrastructure Advantage pattern) |
| Complete infrastructure + DPI | Cross-border Integration | Regional leadership (Digital Leaders pattern) |
| Mid-level both | Balanced Sequencing | Context-dependent optimization |

# Key Findings and Strategic Implications

**Pathway-based analysis of 204 countries validates multiple routes to digital success—enabling differentiated strategies based on country contexts rather than universal prescriptions**

| Key Findings | Policy Implications |
|---|---|
| 1. **Pathway Classification Meaningful:** Tercile-based typology explains 35% revenue, 58% penetration variance<br>2. **Multiple Routes Validated (RQ2):** Infrastructure Advantage ≈ DPI Innovators on revenue (β=-0.02, p=0.978)<br>3. **Leapfrogging Confirmed (RQ2):** 26 countries succeed via DPI (β=7.15 ≈ 4G: β=7.70)<br>4. **Quality > Coverage:** Advanced networks highest returns (3G: 17.14, mobile: 14.64)<br>5. **Complete Systems Critical:** Partial DPI underperforms; integration necessary | 1. **Differentiated strategies** based on pathway position<br>2. **Evidence-based prioritization** using causal magnitudes<br>3. **Regional cooperation** leveraging complementary capabilities<br>4. **Context-aligned sequencing** rejecting universal stages<br>5. **Targeted interventions** by pathway type |

# THANK YOU!