

Accelerating Regional Innovation in India: The Synergy of Digital Governance, AI, and OFDI

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ABSTRACT

AI governance, as a concept, remains strikingly elusive — like trying to nail fog to a wall. Everyone in policy circles talks about it; few have seen a truly functional model in the wild. This paper interrogates how outward foreign direct investment (OFDI), digital governance frameworks, and AI adoption combine — or fail to combine — to shape innovation performance across Indian regions. The present study demonstrates OFDI helps innovation, but whether that relationship is stronger in places where digital infrastructure is robust and AI is genuinely in use. The panel data from 2015 to 2022 and combine econometric modelling with case-based fieldwork, both digital governance quality and AI adoption appear to amplify what OFDI does for regional innovation.

KeyWords: Outward Foreign Direct Investment (OFDI), Regional Innovation Performance, Digital Governance, Artificial Intelligence, Innovation Networks

INTRODUCTION

India's OFDI has expanded considerably over the last two decades — Indian firms have planted flags in Silicon Valley, in pharmaceutical markets across the US and Europe, in African telecoms. The conventional story says this should be good for domestic innovation: firms learn from host-country environments, bring technologies home, upgrade local R&D. Reverse knowledge spillover, the theorists call it (Dunning & Lundan, 2008; Kogut & Zander, 1993). And yet India's regional innovation landscape remains deeply, almost stubbornly, uneven. Karnataka innovates; most other states, much less so. Why?

The story of OFDI and innovation is missing two important variables. One is digital governance: the quality of ICT-enabled public administration, which shapes how easily investment knowledge can be processed, shared, and acted upon in a given region. The other is AI adoption, a set of capabilities for knowledge processing that are now, with remarkable unevenness, embedded in different parts of Indian industry and government.

Taking this motivation seriously, the study adopt a mixed-methods design. The quantitative backbone of the paper uses Two-Stage Least Squares (2SLS) and Generalized Method of Moments (GMM) estimation to address the endogeneity concerns that inevitably arise when studying governance variables alongside economic outcomes. The

qualitative component draws on case evidence from regions that have concentrated both OFDI activity and digital/AI investment, offering texture that regression coefficients alone cannot provide. Together, these strands of evidence suggest that digital governance and AI adoption function as genuine moderators: their presence amplifies what OFDI contributes to regional innovation

The rest of the paper: Section 2 reviews the relevant literatures, which the study try to critically rather than just accumulate. Section 3 describes the data and methodology, including some honest discussion of the measurement challenges. Section 4 presents results. Section 5 draws implications theoretical and practical while being transparent about the limits of what our approach can establish

2. Literature Review

2.1. OFDI, Knowledge Spillovers, and the Innovation Question

The OFDI as an innovation driver rest on a mechanism — reverse knowledge spillover — that is both theoretically compelling and empirical, when a firm from an emerging economy invests in a technologically more advanced host country, it encounters practices, technologies, and management approaches that it would not have developed domestically. Under the right conditions, some of this knowledge travels home. Over time, it enhances the investing firm's own capabilities and, through various

diffusion channels, those of firms in the same region or industry (Xu et al., 2020; Blalock & Simon, 2009).

India is, on its face, an appealing context in which to study this. Pharmaceutical majors like Sun Pharma and Cipla have made strategically important overseas acquisitions specifically to access regulatory know-how and R&D capabilities (Kaushal, 2018). IT firms have similarly leveraged foreign operations to move up the value chain. The empirical literature — Reddy et al. (2022), Behera (2016), among others — tends to find positive effects of OFDI on domestic innovation, at least for high-technology sectors.

The benefits of reverse spillovers are not uniformly distributed across regions. Firms that are already embedded in functioning industrial clusters, with inter-firm networks and strong absorptive capacity, seem to benefit far more than others (Nandrajog, 2020).

This heterogeneity, the study argue, should push researchers toward asking what moderating conditions explain it. Jha and Raghavan (2022) point toward governance quality; Behera (2016) emphasises industrial cluster effects. The study interested in a specific class of moderators: digital governance capability and AI adoption. This is not because the study think other moderators don't matter — they clearly do. It's because these are the conditions that have changed most rapidly in India over the study period, and which therefore offer the most leverage for explaining shifting patterns in OFDI-innovation linkages.

2.2. The AI and Regional Innovation Question

There is a tendency in the recent literature on AI will transform everything; AI-adopting regions will pull ahead; AI is the new electricity. But from where the study stand in 2024, the empirical record on AI and regional innovation — as opposed to AI and firm-level productivity — is considerably thinner than the enthusiasm suggests. AI changes the economics of knowledge processing. Data generated through OFDI operations — on foreign market conditions, customer behaviour, production processes — can be analysed at a scale and speed that the studyre unavailable even ten years ago (Zhou et al., 2021). This is not trivial. A firm that previously had to rely on expensive consultants or slow internal reporting to extract insights from its foreign operations can now, in principle, do so with smaller teams and faster turnaround. In knowledge-intensive sectors, this should translate to faster innovation cycles and better-informed R&D investments.

India's AI geography is worth pausing on. By 2023-24, roughly 48% of key industries had integrated AI in some form — though what 'integrated' means across that figure varies enormously, from sophisticated ML applications to basic automation marketed as AI. Banking and financial services led actual substantive adoption (around 68%), followed by technology firms at 60-65% (Trade.gov, 2025). The government's India AI Mission, launched with over Rs. 10,300 crore in March 2024, signals serious intent. But the reach beyond Bengaluru and Hyderabad is genuinely limited. Precision agriculture AI in Punjab and Madhya Pradesh (Sharma, 2023) and telemedicine

applications in rural areas (Reddy et al., 2021) are real but not yet transformative at scale.

Our theoretical claim is modest: where AI capabilities are more developed, the capacity to absorb and act on knowledge from OFDI activities is higher. This is an absorptive capacity argument (Singh & Batra, 2022), extended to encompass AI as a component of that capacity. The study did not claim AI is the primary driver of regional innovation — that would be overclaiming our evidence.

2.3. Digital Governance

Digital governance has attracted attention primarily from public administration scholars (Meijer & Bolívar, 2016; Heeks, 2017; Bannister & Connolly, 2014), with less cross-fertilisation into the international business and innovation literatures than one might expect. This is unfortunate, because institutional conditions shape spillover processes in important ways that governance scholars have been documenting for years.

India's Digital India initiative, Aadhaar, UPI, and the Common Service Centres are not just service delivery mechanisms — they are, collectively, a transformation of the information environment in which businesses operate. Transparent regulatory processes, digitised compliance systems, and electronic procurement lower the friction involved in acting on knowledge that has been brought back from foreign operations. Ghosh and Ghosh (2021) document real improvements in service delivery; Singh and Singh (2020) find higher private sector participation in digitally-enabled regulatory environments. Sharma et al. (2022) make the more specific claim that digital platforms facilitate knowledge sharing and resource pooling among firms receiving foreign investment.

The distinction matters for policy: if digital governance is merely a control, improving it matters instrumentally but indirectly. If it is a moderator, then improving it specifically in regions with active OFDI creates multiplicative benefits. Our evidence, which the study present below, supports the moderator interpretation.

2.4. Why These Three Things Together?

The study focus specifically on the intersection of OFDI, digital governance, and AI, rather than some other combination of variables. The answer is partly empirical — these are three things that have all changed significantly in India over 2015-2022, which is our study period — and partly theoretical. The complementarity argument holds that digital platforms lower coordination costs for OFDI stakeholders, while AI amplifies the value of the information those platforms generate. Neither alone is sufficient; their intersection is where the leverage is.

Brynjolfsson and McAfee (2014) made the broader case for AI's productivity-enhancing potential; Bansal et al. (2021) document innovation gains from AI application in Indian industry specifically. What has not been tested — and what the study attempt here — is whether AI adoption and digital governance jointly moderate the OFDI-innovation relationship in a way that is visible at the regional level. The synergy hypothesis is, in some ways, the most ambitious part of our theoretical framework, and

the study hold it with appropriate tentativeness.

3. Data and Methodology

3.1. Data Sources

The study to be transparent about measurement before presenting the findings, because some of the choices the study made are contestable. OFDI outflow data come from the Reserve Bank of India's monthly and annual cross-border investment records — these are relatively reliable for equity flows but less comprehensive for certain forms of investment such as intra-company loans and guarantees. Digital governance is proxied using OECD Digital Government Index scores supplemented by India-specific programme data (digital literacy rates, e-government service adoption metrics). These composites are inherently imperfect; digital literacy and e-government adoption are related but not identical constructs, and combining them into a single indicator involves judgment calls.

AI adoption is perhaps the most fraught measurement challenge. The study use region-level proxies — AI-related investment figures and R&D activity data from published National AI Mission and industry reports. These almost certainly undercount AI adoption in smaller firms and service sectors, and they lag actual adoption by the time they appear in official statistics. Patent filings (from the Controller General of Patents, Designs and Trade Marks) and startup density (National Innovation Foundation records) serve as our innovation performance indicators. The study aware that patents under-represent process innovations and incremental improvements, which are common in manufacturing — a limitation the study flag but cannot fully resolve. The panel covers 2015-2022, giving us eight years of variation across Indian states.

3.2. Variables

The dependent variable is regional innovation performance, proxied by patent filings and startup density. The three key independent variables are: OFDI outflows (volume of outward investment by Indian firms in constant prices); digital governance (composite of digital literacy, e-government adoption, OECD DGI-comparable dimensions); and AI adoption (AI investment intensity and AI-related R&D activity at region level). Economic controls include GDP per capita and population density.

3.3. Econometric Approach

Endogeneity is the central methodological challenge. Regions that innovate more may attract more OFDI; governments in high-innovation regions may invest more in digital governance. The study address this through Two-Stage Least Squares (2SLS) estimation, instrumenting digital governance and AI adoption with their lagged values (Wooldridge, 2010). The validity of these instruments is assessed via the Hansen J-statistic (which tests overidentifying restrictions) and Durbin-Wu-Hausman tests (which test for endogeneity). Results from these tests are reported below.

The results complement 2SLS with system GMM estimation (Arellano & Bover, 1995; Blundell & Bond, 1998), which uses both level and difference equations and

handles persistence in the innovation series better than difference-GMM alone — particularly important given that innovation performance, once established in a region, tends to be sticky (Soto, 2009). All interaction terms are constructed using mean-centred predictors (Aiken, 1991; Schielzeth, 2010). VIF values the lower all below 10, indicating no severe multicollinearity.

The core estimation equation is:

$$Innovation_{it} = \beta_0 + \beta_1 OFDI_{it} + \beta_2 (OFDI_{it} \times Digital\ Governance_{it}) + \beta_3 (OFDI_{it} \times AI\ Adoption_{it}) + \beta_4 Controls_{it} + \epsilon_{it}$$

The interaction terms — β_2 and β_3 — are the primary objects of interest. They capture whether and to what degree digital governance and AI adoption modify the OFDI-innovation relationship. The first-stage IV regression instruments OFDI as:

$$OFDI_{it} = \gamma_0 + \gamma_1 Instrument_{it} + \gamma_2 Controls_{it} + v_{it}$$

with the GMM specification augmenting the baseline model with lagged innovation terms to capture dynamic adjustment. The qualitative component draws on case evidence from Karnataka, Maharashtra, and Gujarat — purposively selected as regions varying in OFDI intensity, digital governance quality, and AI adoption — drawing on published policy assessments and, where available, firm-level interview data from secondary sources.

4. Results

4.1. Descriptive Statistics

Table 1 presents summary statistics. Mean OFDI outflows of USD 1.23 billion mask considerable regional variation (standard deviation 0.56B, range 0.5B–2.5B). Digital literacy ranges from 40% to 85% — a spread that reflects the enormous infrastructure gap between digitally advanced urban states and lagging rural ones. AI adoption varies from 5% to 25%, consistent with the concentrated geography of Indian AI discussed in Section 2. Patent filings and startup density show the right-skewed distributions one expects when a small number of metropolitan regions dominate national innovation statistics.

Table 1. Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
OFDI Outflows (USD bn)	1.23	0.56	0.5	2.5
Digital Literacy (%)	65.2	10.1	40	85
AI Adoption Rate (%)	12.5	5.6	5	25
Patent Filings (no.)	120	50	50	250

Startup Density (index)	0.8	0.3	0.3	1.5
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4.2. Correlation Matrix

Table 2 presents pairwise correlations. OFDI outflows correlate negatively with patent filings ($r = -0.21$). This looks odd if you believe the standard spillover story — but it probably reflects a lag structure that correlations cannot capture. Firms redirecting capital abroad may initially draw down domestic R&D investment; the innovation payoffs materialise later. The positive correlation with startup density ($r = +0.12$) is more consistent with the knowledge-and-network effects of international investment showing up in entrepreneurial activity before they show up in formal IP.

Table 2. Correlation Matrix

Variable	OFDI Outflows	Digital Literacy	AI Adoption	Patent Filings	Startup Density
OFDI Outflows	1.000	-0.034	-0.038	-0.212	0.120
Digital Literacy	-0.034	1.000	-0.146	-0.012	-0.082
AI Adoption Rate	-0.038	-0.146	1.000	-0.215	-0.035
Patent Filings	-0.212	-0.012	-0.215	1.000	0.188
Startup Density	0.120	-0.082	-0.035	0.188	1.000

4.3. Regression Results

Table 3 shows the GMM results. OFDI outflows carry a positive and significant coefficient ($\beta = 0.23$, $p < 0.001$), which is reassuring — it would be troubling if the direct OFDI effect were absent. More importantly for our core argument, both interaction terms are positive and significant: OFDI \times Digital Governance ($\beta = 0.12$, $p < 0.001$) and OFDI \times AI Adoption ($\beta = 0.15$, $p < 0.001$). These results hold across multiple model specifications, which reduces our concern that they are artefacts of a particular modelling choice.

Table 3. GMM Regression Results

Variable	Coefficient	Std. Error	t-stat	p-value
OFDI Outflows	0.23	0.05	4.60	0.000

The negative correlation between AI adoption and patent filings ($r = -0.21$). This is not what a simple 'AI drives innovation' story would predict. Our interpretation — and it is an interpretation, not a firm conclusion — is that AI in its current form in India is primarily deployed for operational efficiency (process automation, customer analytics) rather than new-to-world innovation. This is probably true at the current stage of AI diffusion and need not be permanent, but it does complicate the narrative.

Finally, digital literacy shows negligible correlation with either patent filings or startup density. Digital capability in isolation, without complementary funding, policy support, and market access, does not appear sufficient to drive measurable innovation. This is consistent with infrastructure complementarity arguments and with what the study observe in field evidence — digitally literate populations in lagging regions do not automatically innovate more.

OFDI \times Digital Governance	0.12	0.03	4.00	0.000
OFDI \times AI Adoption	0.15	0.04	3.75	0.000
Constant	1.50	0.20	7.50	0.000

4.4. Instrument Validity and Endogeneity Tests

Hansen J-statistic: 5.12, $df = 3$, $p = 0.163$. The study cannot reject the null of instrument validity. Durbin statistic: 4.23, $df = 1$, $p = 0.039$. Wu-Hausman statistic: 5.01, $df = 1$, $p = 0.025$. Both endogeneity tests reject the null of exogeneity, confirming that treating digital governance and AI adoption as exogenous would be inappropriate and validating the IV approach. These results are reported in Tables 4–7.

Table 4. Hansen J-Statistic

Test Statistic	df	p-value
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Hansen J = 5.12	3	0.163
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Table 5. First-Stage Regression (2SLS)

Variable	Coefficient	Std. Error	t-stat	p-value
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Lagged Digital Governance	0.65	0.10	6.50	0.000
Lagged AI Adoption	0.40	0.08	5.00	0.000
Constant	0.20	0.05	4.00	0.000

Table 6. Second-Stage Regression (2SLS)

Variable	Coefficient	Std. Error	t-stat	p-value
Predicted Digital Governance	0.30	0.06	5.00	0.000
Predicted AI Adoption	0.25	0.05	5.00	0.000
OFDI Outflows	0.15	0.03	5.00	0.000
Constant	1.00	0.20	5.00	0.000

Table 7. Endogeneity Tests

Test	Statistic	df	p-value
Durbin	4.23	1	0.039
Wu-Hausman	5.01	1	0.025

4.5. OFDI and Digital Governance

The OFDI × Digital Governance interaction ($\beta = 0.12$) is statistically robust. Our interpretation is that digital governance raises the returns to OFDI by lowering the friction involved in regulatory compliance, cross-sector knowledge exchange, and investment monitoring. In regions where e-governance is more developed, there are better platforms for the knowledge that OFDI generates to circulate and be acted upon.

The Karnataka and Maharashtra cases are instructive — and mildly irritating as case evidence, because they are the obvious success stories and do not tell us much about why other regions haven't followed. Both states have invested heavily in e-governance infrastructure; both lead India's innovation rankings. Whether digital governance caused this or accompanied it is, in truth, difficult to disentangle from regional data alone. The IV approach gives us some traction — lagged digital governance predicts current governance strongly, and the study can argue the instrument does not directly affect current innovation outcomes except through governance — but it does not solve the problem entirely. The study are more confident that the interaction effect is real than the study are about the precise mechanism through which it operates.

4.6. The AI Moderation Effect

The OFDI × AI Adoption coefficient ($\beta = 0.15$) is the largest of the two interaction effects, which is somewhat surprising to us given the relatively low average AI adoption in the sample. A possible explanation: AI capability is concentrated in the same regions that are most active in OFDI (Karnataka, Maharashtra), so the interaction term is picking up a regional clustering effect in addition to the causal mechanism of the hypothesis.

AI adoption appear better positioned to convert the informational inputs of OFDI activities — market intelligence, process data, supply chain signals — into productive innovation. Machine learning tools that identify investment patterns and optimise R&D allocation are likely important pathways (Kumar & Verma, 2022; Sawant & Nair, 2023). The policy implication is that the current concentration of AI capability in a handful of tech hubs may be actively widening India's regional innovation gap. Extending AI infrastructure and skills to OFDI-active but AI-lagging regions could generate disproportionate returns — but this requires targeted policy rather than the broad-brush approach that tends to dominate current discussions.

4.7. Case Evidence

Karnataka's experience broadly matches the synergy hypothesis: firms integrating AI into OFDI decision-making report faster innovation cycles; governance reforms have reduced approval delays; the Bengaluru AI ecosystem creates a talent and knowledge network that amplifies spillover effects from foreign operations. Maharashtra's pattern is somewhat different — AI research partnerships between firms and universities have grown partly in response to demand from OFDI-linked operations, suggesting a pull mechanism rather than a supply-push. Gujarat is the most interesting outlier: strong digital infrastructure and manufacturing OFDI, but relatively lower formal patent activity. This suggests that the innovation benefits of the OFDI-digital governance combination can show up in process improvements and entrepreneurial activity before they register in IP statistics — a reminder of the limitations of patents as an innovation proxy.

5. Discussion

5.1. Theoretical Contributions

The OFDI-innovation question as one of conditionality rather than directionality. The literature has established that OFDI tends, on average, to be good for home-country innovation. Digital governance and AI adoption are important moderators — is not the only possible answer study, but it is an answer that is both theoretically grounded and empirically testable.

The institutional theory connection (Khanna & Palepu, 1997) is worth flagging explicitly. Digital governance is a dimension of institutional quality, and our results suggest it is a particularly relevant one for OFDI-driven innovation — more relevant, perhaps, than broader measures of institutional environment that have been used in prior literature. This is a refinement worth pursuing. Similarly, extending the resource-based view and dynamic capabilities framework (Barney, 1991) to treat AI capability as a regional-level dynamic capability — rather than just a firm-level one — opens an interesting theoretical direction. The concept of 'digital absorptive capacity' that emerges from this work is, the study think, potentially useful for future research, though it needs better operationalisation than the study have been able to provide here.

Knowledge spillover mechanism (Kogut & Zander, 1993) is a firm-level theory that the study are applying to a regional level of analysis. This aggregation is not unproblematic — regional innovation is not simply the sum of firm-level learning. Cluster effects, public good dimensions of knowledge, and institutional coordination

all mediate the relationship in ways our model cannot fully capture. Future work would benefit from multi-level designs that can track knowledge flows from firm to region more explicitly.

5.2. Practical Implications

For policymakers, the takeaway is uncomfortably complex. OFDI promotion, digital governance development, and AI capability building need to be treated as a system rather than as independent policy domains. This is not how Indian policy is currently organised — the Ministry of Electronics and Information Technology handles digital governance; DPIIT handles OFDI promotion; AI is coordinated across multiple ministries under the India AI Mission. The siloing of these policy areas means that synergies the study document in our data are probably being left on the table.

A more specific implication concerns geographic targeting. If the innovation benefits of OFDI are conditional on digital governance and AI capability, and if those conditions are currently concentrated in a few states, then OFDI promotion in other regions will underperform unless it is paired with complementary investment in digital infrastructure and AI skills. This argues for something like 'innovation readiness' criteria in regional OFDI policy — assessing whether a region has the governance and technology conditions to capture spillover benefits, and investing to close gaps where it does not.

For firms, the implication is that location-of-investment decisions should account for home-region conditions, not just host-country conditions. An Indian firm investing abroad from a region with strong digital governance and AI capability will likely generate more domestic innovation benefit than the same investment made from a lagging region — not because the investment itself is different, but because the receiving environment at home is more capable of acting on the knowledge it generates. This is an unusual way of framing OFDI strategy, but one our evidence supports.

One implication of the research: the study are not arguing that AI adoption causes innovation, or that digital governance causes OFDI-spillover benefits in some simple linear way. The relationships the study document are interaction effects in a cross-regional panel, and cross-regional panels are not well-suited to causal inference even with instrumental variables. The research believe the relationships are real, but the study hold our policy claims with appropriate tentativeness

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