

BEYOND ADDITIVE EFFECTS: HOW BUNDLED CAPABILITIES DRIVE FIRM COMPETITIVENESS IN ECONOMIC CORRIDORS

Cheng Ma[†], Faheem Zeb[†], Asad Shahjehan, Liya Zheng^{*}

Abstract

Economic corridors are expected to support green transition, digital upgrading and firm capability development as well as lower transport costs, yet corridor programs usually fund these objectives through separate streams even though firms experience them jointly. This study asks whether firm competitiveness in corridor settings depends on the joint presence of four capability domains: corridor-integrated innovation systems (CIIS), resilient resource reformation (RRR), industrial ecosystem advancement (IEA), and human capital and knowledge networks (HCKN), which together form the CORISE-PK framework. Survey data from 480 corridor-linked firms in five sectors and five regions of Pakistan were analyzed with hierarchical regression and interaction terms. Main effects explain much of the variance in new quality productivity, but two-way and three-way interactions each add explanatory power, and the four-way interaction is positive and significant. The four domains reinforce one another instead of acting as independent drivers, and the synergy estimates are larger, although not significantly so, in higher-technology sectors and in more established corridor regions. The findings imply that green finance is most useful when it supports resource reformation and ecosystem upgrading together, and that digital transformation works as a coordination layer linking knowledge, operations and performance across firms. The paper offers a capability-systems account of corridor competitiveness and guidance on the design of bundled interventions.

Keywords: *sustainable competitiveness; economic corridors; capability complementarities; digital transformation; quality productivity.*

JEL Classification: O33, Q56, L52

Article history: Received: December 2025; Accepted: April 2026; Published: October 2026

1 INTRODUCTION

Economic corridors connect economic agents and nodes along a defined geography and, as Brunner (2013) argues, are not merely transport links but parts of integrated economic networks that change the terms on which firms compete. Firms along a corridor compete on cost and quality, but also on their ability to keep operating when the movement of goods is interrupted and to improve their position in corridor-linked value chains (Brunner, 2013), while green logistics requirements and digitalization raise the standards of service that buyers expect (Makarova et al., 2020). Whether they can do so depends as much on governance, on coordination between public and private actors and on the terms on which local firms enter value chains as on the roads and ports themselves (Dannenberg et al., 2018; Hope & Cox, 2015).

In practice, however, corridor programs continue to be designed and delivered as separate streams. Financing for energy efficiency, the introduction of digital logistics platforms and the provision of vocational training are typically managed by different agencies, each with its own objectives and reporting requirements. This arrangement is difficult to reconcile with how corridors are understood in the literature. Hope and Cox (2015) describe a corridor as a

combination of hard and soft infrastructure projects of different durations that overlap and interact as the corridor develops, and Brunner (2013) argues that the effects of a corridor can be understood only in terms of the network effects it generates within the existing production system. Similar reasoning applies at the level of the firm. Makarova et al. (2020) argue that the benefits of an international transport corridor depend on the parallel development of digital systems, intermodal technologies and management and risk-control systems. Financing, technology and skills are therefore unlikely to be effective in isolation, because the return to each depends on whether the others are in place.

The present study examines this interdependence empirically. It focuses on four capability domains that the authors have drawn from themes in the corridor literature, namely innovation networks and resilience to interruptions of movement (Brunner, 2013), the integration of local firms into value chains (Dannenberg et al., 2018) and skills development as a necessary complement to infrastructure (Quium, 2019): corridor-integrated innovation systems (CIIS), resilient resource reformation (RRR), industrial ecosystem advancement (IEA), and human capital and knowledge networks (HCKN). These domains are defined and related to their theoretical origins in Section 2.4 and are referred to collectively as CORISE-PK (Corridor-Oriented Resilience, Innovation, Sustainability and Excellence – Pakistan). Previous research provides grounds for expecting each domain to be positively associated with firm performance. The question addressed here is whether the association for any one domain is stronger when the other domains are also well developed, that is, whether the domains are complementary.

Pakistan provides an appropriate setting for this question. The China–Pakistan Economic Corridor, one of the flagship projects of the Belt and Road Initiative, includes energy generation, road and rail upgrading, the development of Gwadar port and a number of special economic zones located in provinces at very different stages of industrial development. Corridor-related financing, digital logistics initiatives and skills programs are administered by different agencies and on different timelines, so the fragmentation described above is present in this case. In addition, the sectoral and regional diversity of corridor-linked firms in Pakistan makes it possible to examine whether the strength of complementarities varies with technological intensity and with the maturity of the corridor.

Drawing on survey data from 480 corridor-linked firms, the study estimates hierarchical regression models that introduce two-way, three-way and four-way interaction terms among the four domains. The findings contribute to the corridor literature in two ways. First, they provide firm-level evidence on whether corridor competitiveness is better explained by complementarities among capabilities than by their additive effects. Second, they indicate how financial, digital and organizational interventions might be combined in corridor programs. Green finance and digital transformation are treated in this framework as mechanisms that support the alignment of the four domains rather than as separate explanatory variables.

2 THEORETICAL BACKGROUND

2.1 Corridor competitiveness as a capability ecosystem

Early research on economic corridors was concerned mainly with transport, and corridors were evaluated in terms of reductions in freight costs and travel times and improvements in market access. Brunner (2013) argues that such measures are insufficient, because a corridor generates benefits only as part of a wider network of economic interactions, and subsequent work has extended this view considerably. According to Hope and Cox (2015), a transport route develops into an economic corridor only when logistics services, institutional arrangements and linkages with local businesses are added to the physical infrastructure; they observe that early corridors

such as the Maputo Development Corridor were initially weak in the last of these respects. Dannenberg et al. (2018) examine new-generation growth corridors in the Global South and conclude that whether such corridors integrate local producers into global value chains, or bypass them, depends on the interaction between the state and the lead firms in each chain. Quium (2019), in a review of evidence from South Asia and Sub-Saharan Africa, finds that corridor investment has raised output and employment but that the benefits have been unevenly distributed and accompanied by environmental costs, and that complementary measures for skills development, trade facilitation and coordination are needed if wider benefits are to materialize. The World Bank (2020) reaches a similar conclusion for participation in global value chains more generally, namely that it depends on institutions and policy as much as on connectivity.

The cluster literature helps to explain these findings. Firms located in close proximity benefit from a shared labor market, specialized suppliers and the informal exchange of knowledge (Porter, 1998), but these benefits are realized only by firms that have the capacity to make use of them. In a corridor, the relevant buyers, standards and logistics partners are frequently located at a considerable distance or across a border, so the demands on that capacity are greater. Whether a corridor-linked firm upgrades therefore depends on its own capabilities and on those of the institutions that support it, and not solely on the quality of the infrastructure.

2.2 Sustainable competitiveness beyond cost and quality

The understanding of competitiveness on which this study draws has also broadened over time. The resource-based view attributes sustained competitive advantage to resources and capabilities that competitors cannot easily imitate (Barney, 1991), and the performance measurement literature has long recognized that manufacturers compete on time and flexibility in addition to cost and quality (Neely et al., 1995). Research on supply chain resilience has added a further dimension. Christopher and Peck (2004) and Sheffi (2005) defined resilience as the ability of a supply chain to withstand a disruption and return to normal operation, and later studies identified the capabilities on which it depends, including visibility, flexibility, collaboration with partners and the ability to reconfigure resources (Pettit et al., 2010; Wieland & Wallenburg, 2013; Ambulkar et al., 2015). Sustainability has undergone a comparable change of status, from an external constraint to a dimension of performance. Eccles et al. (2014) report that firms with well-established sustainability practices outperform comparable firms over the long term, and Vachon and Klassen (2008) find that collaborative environmental practices with suppliers, and to a lesser extent with customers, are associated with better manufacturing performance (see Bocken et al., 2014; Rajeev et al., 2017). Corridor-linked firms are subject to all of these pressures simultaneously, since they ship over long distances, operate under the environmental scrutiny that accompanies large infrastructure projects and deal with public agencies of varying capacity. Competitiveness in this setting therefore has to be understood as including the ability to maintain performance under such conditions.

2.3 Green finance and digital transformation

Green finance and digital transformation have both received considerable attention in the recent competitiveness literature, although neither is sufficient on its own to explain the competitiveness of corridor-linked firms. Concessional and blended-finance instruments lower the cost of capital for renewable energy and energy efficiency (Krushelnytska, 2017), and Flammer (2021) finds that firms issuing green bonds subsequently improve their environmental ratings and experience positive stock market reactions. At the corridor level, the World Economic Forum (2022) argues that infrastructure built along Belt and Road corridors will lock in high-carbon development unless green finance, low-carbon technology and supportive policy

are mobilized together. The outcome of a financed project nevertheless depends on the credibility of the institutions that certify it and on the capacity of the firm to implement it. Most studies in this literature model green finance as a direct antecedent of performance and give little attention to the organizational capabilities that determine whether the financed investment is used effectively.

A similar limitation characterizes the literature on digital transformation. Digital technologies are associated with greater visibility and faster decisions across supply chains (Büyükoğkan & Göçer, 2018), but Rai et al. (2006) show that the performance effect of information technology runs through the process integration capability it enables, and the reviews by Vial (2019) and Verhoef et al. (2021) both conclude that the returns to digital investment depend on changes in organizational structure, skills and governance. Most empirical models nevertheless enter digital transformation as a direct predictor of competitiveness.

For these reasons the present study does not test green finance and digital transformation as constructs in their own right. It treats them as enablers whose effect depends on the four capability domains. Green finance lowers the cost of sustainability-oriented investment, but its effects run through firms' ability to reconfigure resource systems and improve ecosystem relationships, so it is most closely associated with RRR and IEA. Digital transformation supplies the measurement, traceability and interoperability infrastructure that coordination and learning require, but its effects depend on firms' knowledge, routines and relational capacity, so it is most closely linked to CIIS and HCKN.

2.4 CORISE-PK as a corridor-adapted capability bundle

The labels used for the four domains are a matter of convenience. Each domain is drawn from an established body of literature, and the purpose of grouping them is to describe the combination of capabilities required of a corridor-linked firm in Pakistan rather than to propose a new theory.

Corridor-integrated innovation systems (CIIS). Innovation systems research established that firms innovate through their links with universities, intermediaries and public agencies and not only through internal R&D (Freeman, 1987; Cooke, 2001), and absorptive capacity research explained why some firms can use those links and others cannot (Cohen & Levinthal, 1990; Zahra & George, 2002). CIIS refers to this capacity as it operates in a corridor, where much of the relevant knowledge arrives through buyers, logistics providers and foreign partners.

Resilient resource reformation (RRR). This domain covers what a firm does with energy, water and materials: raising their productivity, reducing waste and keeping production going when supply is interrupted. It joins the circular economy agenda (Geissdoerfer et al., 2017; Bocken et al., 2014) to the adaptive side of supply chain resilience (Pettit et al., 2010; Ambulkar et al., 2015). The two are grouped because in transport-intensive industries the same investments, in on-site generation or water recycling for instance, serve both ends.

Industrial ecosystem advancement (IEA). Whether a corridor produces a cluster of upgrading firms or an enclave of foreign plants with few local linkages is a central concern of corridor policy. IEA measures the firm's side of that question: its supplier development, its use of shared industrial services and its movement toward higher-value activities, following cluster theory (Porter, 1998; Delgado et al., 2016) and the global value chain literature on upgrading (Humphrey & Schmitz, 2002).

Human capital and knowledge networks (HCKN). Workforce skills and the channels through which firms exchange knowledge with universities and with one another form the fourth

domain (Grant, 1996; Perkmann et al., 2013). Absorptive capacity depends on them, which is why HCKN and CIIS are expected to interact.

2.5 Complementarities and interaction effects

Milgrom and Roberts (1995) showed formally that when practices are complementary the return to adopting one rises with the level of the others, so that a firm adopting the full set does better than the sum of the individual effects would predict. Klein and Sorra (1996) made a related argument about innovation: implementation fails when the organizational climate does not support use of the new practice. Dynamic capabilities research reaches a similar conclusion from a different direction. Firms build and renew advantage in changing environments by reconfiguring bundles of assets, not by accumulating any single one (Teece et al., 1997; Eisenhardt & Martin, 2000; Teece, 2007). Corridor firms operate in exactly such an environment, with buyer requirements, infrastructure and regulation all changing at once.

Applied to the four domains, this reasoning gives specific expectations. Knowledge that reaches a firm through corridor linkages can be used only if the firm has staff able to interpret it, so CIIS should matter more where HCKN is high (Cohen & Levinthal, 1990). Environmental and resource improvements in manufacturing involve suppliers as much as the focal plant (Vachon & Klassen, 2008), so RRR should matter more where IEA is high. Upgrading within a value chain depends on inter-firm cooperation and on the knowledge that buyers transfer along the chain (Humphrey & Schmitz, 2002), so IEA should matter more where HCKN is high. Evidence from adjacent fields is consistent with complementarity of this kind, although it has mostly taken the form of mediation or co-occurrence rather than tested interactions: Rai et al. (2006) find that information technology affects performance only through process integration capability, Wieland and Wallenburg (2013) find that communication and cooperation raise resilience, and Eccles et al. (2014) find that firms with strong sustainability practices also have distinctive organizational processes and higher long-run performance. What has not been tested is whether such effects extend to three- and four-way combinations within a bundle of this kind, or whether they hold for firms in a corridor, where the research has concentrated on infrastructure and regional aggregates and firm-level evidence is thin. The hypotheses in Section 3.1 follow from this reasoning.

2.6 New quality productivity as a higher-order outcome

The dependent variable, new quality productivity (NQP), is not yet a standard construct and requires justification. NQP is conceptualized as a higher-order competitiveness outcome reflecting a common orientation toward superior corridor-relevant performance, not as a narrow operational metric or an aggregate of unrelated indicators. This follows the performance literature in which multidimensional constructs are used when firms compete on composite outcomes (Venkatraman & Ramanujam, 1986; Neely et al., 1995). Corridor-linked firms do not succeed by maximizing cost efficiency, innovation, quality or sustainability separately: innovation that undermines delivery reliability is strategically weak, and cost efficiency achieved through environmentally damaging or fragile processes is unsustainable. NQP is measured with seven items covering innovation-driven productivity, quality, cost efficiency, delivery reliability and sustainability-oriented performance, and it is modeled as a single reflective construct whose measurement properties are reported in Section 4.1. It should be read as a corridor-relevant higher-order construct, not as a claim that its underlying dimensions are interchangeable; the choice is revisited in the limitations.

3 RESEARCH OBJECTIVE, METHODOLOGY AND DATA

3.1 Research objective and hypotheses

<https://doi.org/10.7441/joc.2026.SI.18>

The objective is to establish whether the performance of corridor firms is better explained by additive capability effects or by complementarities across the CORISE-PK domains. The analysis proceeds from main effects through two-way, three-way and four-way interaction terms, and then compares the four-way term across sectors and regions.

H1: CIIS, RRR, IEA and HCKN are each positively associated with NQP.

H2: Two-way interactions among CIIS, RRR, IEA and HCKN are positively associated with NQP.

H3: Three-way interactions among CIIS, RRR, IEA and HCKN are positively associated with NQP.

H4: The four-way interaction (CIIS $\times$ RRR $\times$ IEA $\times$ HCKN) is positively associated with NQP.

H5: The four-way synergy is stronger in higher-technology sectors and in more established corridor regions.

3.2 Sample and data collection

The target population comprised industrial firms operating within or connected to Pakistan's corridor economy, defined as enterprises located within roughly 50 kilometers of major corridor routes or industrial zones, or with documented operational links to corridor infrastructure, logistics platforms or related development programs. A multistage stratified purposive design was used, with regions as primary strata and sectors as secondary strata; firms were then selected within each region–sector cell on corridor exposure criteria, from listings compiled by the Board of Investment, SMEDA, CPEC-related directories and industry associations.

Data were collected through four modes (Tab. 1). Face-to-face administration was used where clarification of the questionnaire was helpful, email and online modes reached dispersed firms, and telephone administration was used for firms without reliable internet access. Of the 500 firms selected, 480 provided usable firm-level data after screening for completeness, consistency and eligibility, a firm-level response rate of 96%. In each firm, ratings were obtained from four or five functional informants and aggregated to the firm level after within-firm agreement checks (James et al., 1984; Bliese, 2000). The same wording, item order, response scale and instructions were used in every mode, although mode-based differences in response tendencies cannot be excluded entirely.

Tab. 1 – Data collection summary. Source: own research

Collection method	Number of firms	Percentage	Response rate
Face-to-face surveys	280	56.0%	100%
Email surveys	120	24.0%	88%
Online surveys	70	14.0%	93%
Telephone	30	6.0%	100%
Total	500	100.0%	96%

Tab. 2 – Firm characteristics (n = 480). Source: own research

Characteristic	Category	Frequency	Percentage
Firm size	Small (10–49)	135	28.1%
	Medium (50–249)	170	35.4%
	Large (250+)	175	36.5%
Years in operation	Less than 5 years	90	18.8%
	5 to 10 years	176	36.7%
	More than 10 years	214	44.6%
Corridor engagement	Direct	350	72.9%
	Indirect	130	27.1%

Tab. 3 – Sectoral and regional distribution (n = 480). Source: own research

Sector	Punjab	KP	Sindh	Balochistan	GB	Total	%
Textiles	73	22	19	8	8	130	27.1%
Agribusiness	44	29	15	9	9	106	22.1%
Logistics	29	20	24	9	5	87	18.1%
Energy	24	19	20	10	5	78	16.3%
Engineering	15	15	19	19	11	79	16.5%
Total	185	105	97	55	38	480	100%

Note: KP = Khyber Pakhtunkhwa; GB = Gilgit-Baltistan.

Tab. 2 and 3 describe the sample. Small, medium and large firms are represented in roughly equal proportions, most firms have operated for more than five years, and 73% report direct engagement with corridor infrastructure or programs. Textiles and agribusiness account for just under half of the sample, and Punjab contributes the largest share of firms, followed by Khyber Pakhtunkhwa and Sindh. For the subgroup tests under H5, engineering and energy were treated as higher-technology sectors because they are more technology- and capital-intensive and depend more on technical upgrading and specialized knowledge; textiles, agribusiness and logistics were treated as traditional sectors because their dominant operating models in the sampled context are less R&D-intensive and more process-oriented. Punjab, Sindh and Khyber Pakhtunkhwa were classified as established corridor regions on the basis of infrastructure, industrial concentration, logistics connectivity and the depth of corridor-linked business activity; Balochistan and Gilgit-Baltistan, where corridor connectivity and industrial development are less mature, were classified as emerging regions. These classifications serve only for subgroup comparison.

Because predictor and outcome measures were collected in one survey wave from informants within the same firm, common method bias was treated as a design risk. Following Podsakoff et al. (2003), respondents were assured of anonymity and confidentiality, items were refined through expert review and pilot testing, construct blocks were separated into distinct sections, item wording was kept concise, and the instructions stated that there were no right or wrong answers and asked for responses reflecting actual conditions.

3.3 Measures

The CORISE-PK domains were measured with multi-item scales developed from the literature and adapted to the corridor context: six items for CIIS, five for RRR, seven for IEA, six for HCKN and seven for NQP, all on the same five-point agreement scale. Tab. 4 lists the item counts, indicative sources and an illustrative item for each construct. Firm size and firm age were entered as ordinal control variables using the categories shown in Tab. 2, and sector (higher-technology vs. traditional), region (established vs. emerging) and corridor engagement (direct vs. indirect) as binary indicators; the sector and region indicators also served as the grouping variables for the subgroup analyses.

Tab. 4 – Construct operationalization. Source: own research

Construct	Items	Indicative sources	Sample item (illustrative)
CIIS	6	OECD/Eurostat (2005); Cooke (2001); Tödtling & Trippel (2005)	"Our firm actively collaborates with universities on R&D projects"
RRR	5	Pettit et al. (2010); UNIDO (2021); Geissdoerfer et al. (2017)	"We have implemented water recycling systems in production"

IEA	7	Porter (1998); Humphrey & Schmitz (2002); Delgado et al. (2016)	"Our firm benefits from supplier networks in the corridor"
HCKN	6	Grant (1996); Perkmann et al. (2013); Cohen & Levinthal (1990)	"We regularly engage diaspora experts for knowledge transfer"
NQP	7	Kaplan & Norton (1996); Juran (1995); Neely et al. (1995)	"Our productivity has improved through innovation adoption"

3.4 Analytical strategy

Hierarchical regression was used. Model 1 contains the main effects of CIIS, RRR, IEA and HCKN together with the control variables (firm size, firm age, sector, region and corridor engagement); Model 2 adds the six two-way interactions; Model 3 adds the four three-way interactions; and Model 4 adds the four-way interaction. Variables were mean-centered before interaction terms were formed (Aiken & West, 1991). Incremental explanatory power was assessed with the change in R^2 and the associated F-change statistic, and multicollinearity was checked at each step with the condition index, using 30 as the reference point (Hair et al., 2019).

Common method bias was assessed post hoc with three diagnostics, since no single test is conclusive (Podsakoff et al., 2003): Harman's single-factor test, an unmeasured common latent factor added to the confirmatory measurement model with standardized loadings compared with and without it, and a marker-variable procedure using a theoretically unrelated construct (Lindell & Whitney, 2001). To test H5, the full interaction model was re-estimated separately for higher-technology and traditional sectors and for established and emerging corridor regions, and the four-way coefficients were compared across subgroups with the z-test for the difference between independent regression coefficients (Paternoster et al., 1998).

4 RESULTS AND DISCUSSION

4.1 Measurement quality

Confirmatory factor analysis indicated good measurement-model fit (Tab. 5). The chi-square statistic is significant, as expected with a sample of this size, but RMSEA (0.045) and SRMR (0.039) meet the cutoffs proposed by Hu and Bentler (1999), and the normed chi-square (1.97), CFI (0.943) and TLI (0.927) satisfy the conventional criteria of 3.0 and 0.90 (Hair et al., 2019). Cronbach's alpha and composite reliability are at least 0.78 for every construct, and average variance extracted exceeds 0.50 (Fornell & Larcker, 1981; Tab. 6). The common method bias diagnostics (Tab. 7) show that the first unrotated factor explained 27.4% of the total variance, that the differences between substantive loadings in the baseline and common-latent-factor models were below 0.18, and that the marker-variable adjustment was non-significant ($p > 0.10$). These results reduce, but do not remove, the possibility that the findings are influenced by the common measurement source.

Tab. 5 – Measurement model fit indices. Source: own research

Fit index	Value	Threshold	Interpretation
Chi-square (χ^2)	835.27	—	Significant ($p < 0.001$); sensitive to sample size
Degrees of freedom (df)	424	—	—
χ^2/df	1.97	< 3.0	Meets threshold
CFI	0.943	≥ 0.90	Meets threshold
TLI	0.927	≥ 0.90	Meets threshold
RMSEA	0.045	≤ 0.06	Meets threshold
SRMR	0.039	≤ 0.08	Meets threshold

Tab. 6 – Construct reliability and convergent validity. Source: own research

Construct	Cronbach's α	Composite reliability	AVE	$\sqrt{\text{AVE}}$
CIIS	0.81	0.84	0.56	0.75
RRR	0.78	0.82	0.53	0.73
IEA	0.84	0.86	0.59	0.77
HCKN	0.80	0.83	0.55	0.74
NQP	0.86	0.88	0.61	0.78

Tab. 7 – Common method bias diagnostics. Source: own research

Diagnostic	Result	Threshold	Interpretation
Harman's single-factor test	First factor explains 27.4% of total variance	< 50%	No single dominant factor
Common latent factor (CLF)	Absolute differences in standardized loadings < 0.18	< 0.20	Method-factor influence limited
Marker-variable test	Marker adjustment non-significant ($p > 0.10$)	$p > 0.05$	No evidence that common method variance materially affects the model

4.2 Main effects and the incremental value of complementarities

The main-effects model explains a substantial share of the variance in NQP ($R^2 = 0.680$; adjusted $R^2 = 0.674$; $F(9, 470) = 111.00$, $p < 0.001$), and each of the four domains is positively and significantly associated with NQP (Tab. 8), supporting H1. Adding the two-way interactions raises explanatory power by $\Delta R^2 = 0.045$ ($F(6, 464) = 12.65$, $p < 0.001$), the three-way interactions add a further $\Delta R^2 = 0.028$ ($F(4, 460) = 13.04$, $p < 0.001$), and the full model including the four-way interaction reaches $R^2 = 0.771$ (adjusted $R^2 = 0.761$; $F(1, 459) = 36.08$, $p < 0.001$; Tab. 8, Panel B). Controls and main effects together account for 88.2% of the explained variance, two-way interactions for 5.8%, three-way interactions for 3.6% and the four-way term for 2.3% (Tab. 10). Collinearity increased with the higher-order terms, as expected, but the maximum condition index rose only from 14.76 in Model 1 to 28.67 in Model 4, below the threshold of 30.

Tab. 8 – Main effects and hierarchical model progression. Source: own research

Panel A. Main effects (Model 1)

	CIIS	RRR	IEA	HCKN
Standardized β	0.31	0.28	0.34	0.29
p value	< 0.001	< 0.001	< 0.001	< 0.001
f^2	0.27	0.21	0.31	0.22

Panel B. Model progression

Model step	Predictors included	No. of predictors	R^2	Adjusted R^2	ΔR^2	F-change (df)	p value	Max CI
Model 1	Controls + main effects	9	0.680	0.674	—	$F(9, 470) = 111.00^a$	< 0.001	14.76
Model 2	Model 1 + six two-way interactions	15	0.725	0.716	0.045	12.65 (6, 464)	< 0.001	19.84
Model 3	Model 2 + four three-way interactions	19	0.753	0.743	0.028	13.04 (4, 460)	< 0.001	24.91
Model 4	Model 3 + four-way interaction	20	0.771	0.761	0.018	36.08 (1, 459)	< 0.001	28.67

Note: Panel A reports standardized coefficients from Model 1, controlling for firm size, firm age, sector, region and corridor engagement; f^2 = Cohen's effect size for each predictor; all four coefficients are significant at $p < 0.001$. Panel B: ^a overall model F-test for Model 1, which has no preceding step; for Models 2–4 the F-change statistic is shown with its degrees of freedom in parentheses. Max CI = maximum condition index (reference value 30; Hair et al., 2019).

All six two-way interactions are positive and significant (Tab. 9), supporting H2. The strongest is $RRR \times IEA$ ($\beta = 0.24$, $p < 0.001$), followed by $IEA \times HCKN$ ($\beta = 0.22$, $p = 0.002$) and $CIIS \times HCKN$ ($\beta = 0.21$, $p = 0.003$); the weakest, $RRR \times HCKN$ ($\beta = 0.14$, $p = 0.046$), remains significant at the 5% level. All four three-way interactions are also positive and significant (Tab. 9), supporting H3, with $CIIS \times RRR \times IEA$ the largest ($\beta = 0.28$, $p < 0.001$).

Tab. 9 – Two-way and three-way interaction effects on NQP. Source: own research

Two-way interactions (Model 2)

	$CIIS \times RRR$	$CIIS \times IEA$	$CIIS \times HCKN$	$RRR \times IEA$	$RRR \times HCKN$	$IEA \times HCKN$
β	0.18*	0.15*	0.21**	0.24***	0.14*	0.22**
p value	0.010	0.013	0.003	< 0.001	0.046	0.002

Three-way interactions (Model 3)

	$CIIS \times RRR \times IEA$	$CIIS \times RRR \times HCKN$	$CIIS \times IEA \times HCKN$	$RRR \times IEA \times HCKN$
β	0.28***	0.23*	0.26**	0.20*
p value	< 0.001	0.011	0.001	0.027

Note: Standardized coefficients of mean-centered product terms from Model 2 (two-way) and Model 3 (three-way) of the hierarchical regression (Tab. 8, Panel B). *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Tab. 10 – Variance decomposition by interaction level. Source: own research

Source	ΔR^2 (increment)	Cumulative R^2	Percentage of total	Cumulative %
Controls + main effects	0.680	0.680	88.2%	88.2%
Two-way interactions	0.045	0.725	5.8%	94.0%
Three-way interactions	0.028	0.753	3.6%	97.7%
Four-way interaction	0.018	0.771	2.3%	100.0%
Total R^2	0.771	0.771	100.0%	—

Note: ΔR^2 = increment in R^2 at each step of the hierarchical regression (Tab. 8, Panel B); cumulative R^2 equals the R^2 of the corresponding model. Percentages express each increment as a share of the final R^2 (0.771).

4.3 System-level synergy: the four-way interaction

The four-way interaction ($CIIS \times RRR \times IEA \times HCKN$) is positive and significant ($\beta = 0.34$, $SE = 0.057$, $t = 6.00$, $p < 0.001$), supporting H4: gains in corridor competitiveness are largest when the full capability bundle is jointly present. Higher-order interaction models place heavy demands on estimation, so the coefficient is interpreted together with the collinearity diagnostics above, which indicate that the full model remains within acceptable bounds. It should be read as evidence of synergy conditional on the observed range and covariance structure of the sample, not as a stand-alone marginal effect.

Tab. 11 reports the four-way coefficient by subgroup. The point estimate is larger in higher-technology sectors ($\beta = 0.41$, $p < 0.001$) than in traditional sectors ($\beta = 0.26$, $p = 0.019$), and larger in established corridor regions ($\beta = 0.38$, $p < 0.001$) than in emerging regions, where the coefficient is positive but only marginally significant ($\beta = 0.21$, $p = 0.084$). H5 therefore receives directional support only, because the differences between the subgroup coefficients are not statistically significant (sectors: $z = 1.01$, $p = 0.31$; regions: $z = 1.13$, $p = 0.26$). Because subgroup estimation reduces the effective sample size and can magnify instability in high-order interaction models, these coefficients are best read as directional evidence of heterogeneity.

Tab. 11 – Context sensitivity of the four-way synergy. Source: own research

Context	β (four-way)	SE	p value	Interpretation
Traditional sectors (n = 323)	0.26*	0.11	0.019	Moderate synergy
Higher-technology sectors (n = 157)	0.41***	0.10	< 0.001	Strong synergy
Established regions (n = 387)	0.38***	0.09	< 0.001	Strong synergy
Emerging regions (n = 93)	0.21†	0.12	0.084	Weak (marginal) synergy

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; † $p < 0.10$. Sector and region classifications are defined in Section 3.2. Differences between subgroup coefficients are not statistically significant (sectors: $z = 1.01$, $p = 0.31$; regions: $z = 1.13$, $p = 0.26$).

4.4 Discussion and implications for green finance and digital transformation

The results indicate that corridor competitiveness depends on how the four capability domains combine, not on the level of any one of them. Main effects are large, but each step from two-way to four-way interaction adds explanatory power, which is what complementarity theory predicts and what the corridor literature has assumed without testing at firm level.

The ordering of the two-way effects matches the expectations set out in Section 2.5. The largest coefficient belongs to $RRR \times IEA$, and the next two, $IEA \times HCKN$ and $CIIS \times HCKN$, both involve knowledge networks. The smallest, $RRR \times HCKN$, was not among the pairings for which a mechanism was proposed, and its weaker effect suggests that resource improvement draws on operational and supplier relationships more than on external knowledge channels. Among the three-way terms, $CIIS \times RRR \times IEA$ is the largest. The productive core of the bundle therefore appears to lie in the alignment of innovation activity, resource use and supplier relationships, with knowledge networks raising the return to that core.

The subgroup estimates suggest, although the differences are not statistically significant, that the strength of this synergy varies with context. The four-way term is larger among engineering and energy firms than among textile, agribusiness and logistics firms, and larger in Punjab, Sindh and Khyber Pakhtunkhwa than in Balochistan and Gilgit-Baltistan, where it is only marginally significant. One reading is that interdependence among the domains grows with the technical complexity of what the firm makes and with the density of the industrial environment around it. Where suppliers, service providers and training institutions are sparse, as in the emerging regions, a firm's own capabilities have fewer counterparts to combine with, and the synergy is correspondingly weaker.

Two implications follow, with the caveat that they are inferences from the capability results and not tests of particular instruments. The first relates to the design of corridor programs. A policy that funds only innovation, only resource efficiency or only training will not obtain the returns observed here unless the other domains are developed alongside it, which argues for corridor programs, and special economic zone packages in particular, that combine plant-level finance with supplier development and technical training. The second relates to green finance and digital transformation. Although the study did not measure specific instruments or technologies, the results indicate where each is likely to be most useful: green finance where it funds resource reformation and ecosystem upgrading together, as when clean-energy or water-efficiency investment is tied to supplier development, and digital transformation as the layer that links knowledge flows, operations and performance measurement across firms. For managers, the practical task is to align initiatives that are usually run separately, in innovation, operations, supplier development and workforce learning. For provincial agencies in the

emerging corridor regions, the smaller four-way estimate, although it does not differ significantly from that of the established regions, suggests that building supplier networks and training capacity should come first, or at least at the same time as financing for plant-level upgrading.

5 CONCLUSION

This study set out to test whether the performance of corridor-linked firms in Pakistan is better explained by the sum of four capability domains or by their combination. The evidence supports the second of these explanations. Main effects account for most of the explained variance, but interactions among the domains add to it at every order, and the four-way term is positive and significant, so that the return to investing in any one domain depends on the state of the other three. The point estimates are largest in technology-intensive sectors and in the more established corridor regions, although these differences are not statistically significant. For corridor authorities the finding argues against single-objective programming and for interventions whose components are coupled, sequenced and assessed against shared indicators; for investors it argues for financing that is matched to the coordination and skills capacity of the firms and regions it reaches.

6 LIMITATIONS

This study has several limitations. The data are cross-sectional and, although ratings from several informants were aggregated for each firm, predictors and outcome were reported by informants from the same firm in one survey wave. The procedural remedies and the three diagnostics reported in Sections 3 and 4 reduce the risk of common method bias but cannot eliminate it, and the design does not permit causal inference, so the findings should be interpreted as evidence of association. The sample was selected purposively within region–sector strata and not at random, which limits the extent to which the results can be generalized to all corridor-linked firms, and the data were collected through several modes whose possible effects on responses were not modeled. The classification of sectors by technological intensity and of regions by corridor maturity is necessarily broad and may conceal differences within each group. NQP was modeled as a single higher-order construct, and green finance exposure and digital transformation intensity were captured only indirectly. Direct measures of these enablers, longitudinal data and separate models for the individual dimensions of NQP would allow the conclusions drawn here to be tested more rigorously.

Acknowledgement

The authors used an AI-assisted tool for language refinement and improvement of the manuscript.

REFERENCES

- Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Sage.
- Ambulkar, S., Blackhurst, J., & Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management*, 33–34, 111–122. <https://doi.org/10.1016/j.jom.2014.11.002>
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. <https://doi.org/10.1177/014920639101700108>
- Bliese, P. D. (2000). Within-group agreement, non-independence, and reliability: Implications for data aggregation and analysis. In K. J. Klein & S. W. J. Kozlowski (Eds.), *Multilevel*

- theory, research, and methods in organizations: Foundations, extensions, and new directions* (pp. 349–381). Jossey-Bass.
- Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, 65, 42–56. <https://doi.org/10.1016/j.jclepro.2013.11.039>
- Brunner, H.-P. (2013). *What is economic corridor development and what can it achieve in Asia's subregions?* (ADB Working Paper Series on Regional Economic Integration No. 117). Asian Development Bank.
- Büyükoğkan, G., & Göçer, F. (2018). Digital supply chain: Literature review and a proposed framework for future research. *Computers in Industry*, 97, 157–177. <https://doi.org/10.1016/j.compind.2018.02.010>
- Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management*, 15(2), 1–14. <https://doi.org/10.1108/09574090410700275>
- Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), 128–152. <https://doi.org/10.2307/2393553>
- Cooke, P. (2001). Regional innovation systems, clusters, and the knowledge economy. *Industrial and Corporate Change*, 10(4), 945–974. <https://doi.org/10.1093/icc/10.4.945>
- Dannenberg, P., Revilla Diez, J., & Schiller, D. (2018). Spaces for integration or a divide? New-generation growth corridors and their integration in global value chains in the Global South. *Zeitschrift für Wirtschaftsgeographie*, 62(2), 135–151. <https://doi.org/10.1515/zfw-2017-0034>
- Delgado, M., Porter, M. E., & Stern, S. (2016). Defining clusters of related industries. *Journal of Economic Geography*, 16(1), 1–38. <https://doi.org/10.1093/jeg/lbv017>
- Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The impact of corporate sustainability on organizational processes and performance. *Management Science*, 60(11), 2835–2857. <https://doi.org/10.1287/mnsc.2014.1984>
- Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: What are they? *Strategic Management Journal*, 21(10–11), 1105–1121. [https://doi.org/10.1002/1097-0266\(200010/11\)21:10/11<1105::AID-SMJ133>3.0.CO;2-E](https://doi.org/10.1002/1097-0266(200010/11)21:10/11<1105::AID-SMJ133>3.0.CO;2-E)
- Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2), 499–516. <https://doi.org/10.1016/j.jfineco.2021.01.010>
- Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1), 39–50. <https://doi.org/10.1177/002224378101800104>
- Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. Pinter.
- Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. <https://doi.org/10.1016/j.jclepro.2016.12.048>
- Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17(S2), 109–122. <https://doi.org/10.1002/smj.4250171110>
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage.
- Hope, A., & Cox, J. (2015). *Development corridors* (EPS-PEAKS Topic Guide). Coffey International Development.

- Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, 6(1), 1–55. <https://doi.org/10.1080/10705519909540118>
- Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, 36(9), 1017–1027. <https://doi.org/10.1080/0034340022000022198>
- James, L. R., Demaree, R. G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology*, 69(1), 85–98. <https://doi.org/10.1037/0021-9010.69.1.85>
- Juran, J. M. (1995). *A history of managing for quality: The evolution, trends, and future directions of managing for quality*. ASQC Quality Press.
- Kaplan, R. S., & Norton, D. P. (1996). *The balanced scorecard: Translating strategy into action*. Harvard Business School Press.
- Klein, K. J., & Sorra, J. S. (1996). The challenge of innovation implementation. *Academy of Management Review*, 21(4), 1055–1080. <https://doi.org/10.2307/259164>
- Krushelnyska, O. (2017). *Introduction to green finance*. World Bank Group; Global Environment Facility.
- Lindell, M. K., & Whitney, D. J. (2001). Accounting for common method variance in cross-sectional research designs. *Journal of Applied Psychology*, 86(1), 114–121. <https://doi.org/10.1037/0021-9010.86.1.114>
- Makarova, I., Shubenkova, K., Buyvol, P., Mavrin, V., Gabsalikhova, L., & Mukhametdinov, E. (2020). International transport corridors: Impact on territorial development. In *Proceedings of the International Conference "New Silk Road: Business Cooperation and Prospective of Economic Development" (NSRBCPED 2019)* (pp. 654–662). Atlantis Press. <https://doi.org/10.2991/aebmr.k.200324.122>
- Milgrom, P., & Roberts, J. (1995). Complementarities and fit: Strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, 19(2–3), 179–208. [https://doi.org/10.1016/0165-4101\(94\)00382-F](https://doi.org/10.1016/0165-4101(94)00382-F)
- Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management*, 15(4), 80–116. <https://doi.org/10.1108/01443579510083622>
- OECD/Eurostat. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data* (3rd ed.). OECD Publishing.
- Paternoster, R., Brame, R., Mazerolle, P., & Piquero, A. (1998). Using the correct statistical test for the equality of regression coefficients. *Criminology*, 36(4), 859–866. <https://doi.org/10.1111/j.1745-9125.1998.tb01268.x>
- Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy*, 42(2), 423–442. <https://doi.org/10.1016/j.respol.2012.09.007>
- Pettit, T. J., Fiksel, J., & Croxton, K. L. (2010). Ensuring supply chain resilience: Development of a conceptual framework. *Journal of Business Logistics*, 31(1), 1–21. <https://doi.org/10.1002/j.2158-1592.2010.tb00125.x>
- Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), 879–903. <https://doi.org/10.1037/0021-9010.88.5.879>

- Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review*, 76(6), 77–90.
- Quium, A. S. M. A. (2019). Transport corridors for wider socio-economic development. *Sustainability*, 11(19), 5248. <https://doi.org/10.3390/su11195248>
- Rai, A., Patnayakuni, R., & Seth, N. (2006). Firm performance impacts of digitally enabled supply chain integration capabilities. *MIS Quarterly*, 30(2), 225–246. <https://doi.org/10.2307/25148729>
- Rajeev, A., Pati, R. K., Padhi, S. S., & Govindan, K. (2017). Evolution of sustainability in supply chain management: A literature review. *Journal of Cleaner Production*, 162, 299–314. <https://doi.org/10.1016/j.jclepro.2017.05.026>
- Sheffi, Y. (2005). *The resilient enterprise: Overcoming vulnerability for competitive advantage*. MIT Press.
- Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(13), 1319–1350. <https://doi.org/10.1002/smj.640>
- Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509–533. [https://doi.org/10.1002/\(SICI\)1097-0266\(199708\)18:7<509::AID-SMJ882>3.0.CO;2-Z](https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z)
- Tödtling, F., & Trippel, M. (2005). One size fits all? Towards a differentiated regional innovation policy approach. *Research Policy*, 34(8), 1203–1219. <https://doi.org/10.1016/j.respol.2005.01.018>
- UNIDO. (2021). *Industrial development report 2022: The future of industrialization in a post-pandemic world*. United Nations Industrial Development Organization.
- Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International Journal of Production Economics*, 111(2), 299–315. <https://doi.org/10.1016/j.ijpe.2006.11.030>
- Venkatraman, N., & Ramanujam, V. (1986). Measurement of business performance in strategy research: A comparison of approaches. *Academy of Management Review*, 11(4), 801–814. <https://doi.org/10.5465/amr.1986.4283976>
- Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>
- Wieland, A., & Wallenburg, C. M. (2013). The influence of relational competencies on supply chain resilience: A relational view. *International Journal of Physical Distribution & Logistics Management*, 43(4), 300–320. <https://doi.org/10.1108/IJPDLM-08-2012-0243>
- World Bank. (2020). *World development report 2020: Trading for development in the age of global value chains*. World Bank.
- World Economic Forum. (2022). *Advancing the green development of the Belt and Road Initiative: Harnessing finance and technology to scale up low-carbon infrastructure*. World Economic Forum.
- Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review*, 27(2), 185–203.

Contact Information

Cheng Ma[†]

Business School, Qingdao University, Qingdao, Shandong, China

Email: mc_0812@163.com

ORCID: 0000-0002-0927-4257

Faheem Zeb[†]

Business School, Qingdao University, Qingdao, Shandong, China

Email: faheemzeb@yahoo.com

ORCID: 0000-0003-0844-6827

Asad Shahjehan

Department of Management Sciences, Hazara University, Pakistan

Email: asad@hu.edu.pk

ORCID: 0000-0003-2993-9276

Liya Zheng*

Research Center for the Regional Comprehensive Economic Partnership (RCEP) Member States,
Ningbo University of Finance & Economics, Ningbo, Zhejiang, China.

School of Accounting, Ningbo University of Finance & Economics, Ningbo, Zhejiang, China.

Email: zhengliya@nbufe.edu.cn and 767718086@qq.com

ORCID: 0000-0003-2285-1810

*** Corresponding author**

Note: [†] Cheng Ma and Faheem Zeb contributed equally to this work and share first authorship.