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The Double-Edged Sword of Digital Transformation in Cultural Scenic Areas: Heterogeneous Moderation of Qilu Cultural Genes on Technology-Value Conversion Paths

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ABSTRACT: How can cultural attractions that invest similarly in digital technologies arrive at such different outcomes? We address this question by turning to regional culture. Grounded in dynamic capabilities theory and service-dominant logic, this study investigates how Qilu cultural genes, a regional cultural tradition rooted in Shandong Province, conditions the conversion of digital initiatives into value. Hypotheses were tested with PLS-SEM on visitor-level survey data from 566 visitors across ten cultural attractions in Shandong, China, with supply-side assessments from 28 managers aggregated to the scenic-area level. The results show that Qilu cultural heritage neither simply promotes nor obstructs digital transformation. Rather, it works like a selective lens, strengthening technological pathways that carry cultural meaning and weakening those that lack it. Among the three conversion paths examined, experience-activated digitalisation contributes most to visitors' digital value co-creation capability, and the slope of this path increases by 48.2% when visitors score one standard deviation above the mean on Qilu cultural gene strength. Infrastructure-focused digitalisation, the second most effective path on average, sees its conversion efficiency drop by 38.1% at the same high level of gene strength. By comparison, the ecosystem-based path shows no such cultural dependence. Taken together, these findings reveal that a single cultural tradition can simultaneously enable and constrain digital transformation. For managers, the implication is clear. Digital investment should be tailored to visitors' cultural profiles rather than spread uniformly across all initiatives.

KEYWORDS: Qilu cultural genes, cultural scenic areas, digital transformation, value co-creation, moderating effect.

INTRODUCTION

The deep integration of digital technology and cultural heritage has fundamentally reshaped how tourists experience, interpret, and co-create value at scenic destinations. In China, national strategies such as the Digital China initiative and the National Cultural Digitisation Strategy have channelled substantial public and private investment into smart ticketing, augmented reality guided tours, immersive performances, and cross-platform data ecosystems. Shandong Province, home to Mount Tai and the Three Confucian Sites in Qufu, stands at the forefront of this movement. Yet a persistent puzzle remains. Despite comparable levels of technology investment, some attractions witness enthusiastic visitor engagement while others encounter indifference or even resistance. Dazzling LED screens and algorithmic crowd-control systems have drawn complaints about the coldness of technological discipline in certain heritage sites, whereas modest AR overlays have generated viral word-of-mouth and deep cultural engagement elsewhere. This heterogeneity in transformation effectiveness cannot be explained by technology intensity alone. It points to a more subtle mechanism in which regional culture selectively shapes how visitors interpret and respond to different technological interfaces.

Existing cross-cultural research typically treats culture as a control variable or a national-level grouping dummy, assuming a uniform directional effect across technological contexts. This study challenges that assumption by introducing Qilu cultural genes as a continuous boundary condition that moderates the technology-capability link in opposite directions depending on the technology layer. The core proposition is straightforward yet powerful. The same cultural DNA can simultaneously accelerate and decelerate digital transformation. For visitors deeply imbued with Qilu cultural genes, digitally activated cultural content such as AR reconstructions of Confucian ceremonial rites resonates profoundly and triggers heightened co-creation engagement. By contrast, the same visitors tend to view naked infrastructure such as ubiquitous sensors and automated gates as a disturbance to the sanctity of the heritage site, thereby diminishing the marginal return on hardware investment.

Empirically, this study adopts a dual-source measurement architecture. Visitor questionnaires capture demand-side perceptions of technology, capability, and cultural value, while manager questionnaires provide supply-side assessments of co-creation capability and economic performance. The two sources are validated through confirmatory factor analysis and the supply-side source is aggregated to the scenic-area level before entering the analysis. Data were collected from 566 visitors and 28 managers across ten cultural scenic areas in Shandong. Analysis follows a nested strategy, AMOS 26.0 for the dedicated measurement tests, SmartPLS 4.0 for the visitor-level structural model with mediation and moderation tests,

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and a two-level model for the supply-side outcome.

LITERATURE REVIEW

Core Concepts

Digital technology adoption in the cultural tourism context can be decomposed into three functionally distinct layers. Digital infrastructure constitutes the resource layer, encompassing networks, terminals, and data platforms that reduce search costs and queuing friction. Digital experience activation constitutes the content layer, including AR/VR immersion, digital narrative, and participatory content that directly elicits visitor emotional engagement. Digital ecosystem construction constitutes the network layer, covering back-end OTA integration, cross-platform data protocols, and multi-stakeholder collaboration that reconfigures organisational boundaries. Visitors experience ecosystem construction not as back-end machinery but through its downstream consequences, such as seamless ticketing across platforms and consistent service across channels. Because these three layers occupy different positions in the value chain, they are not mutually substitutable.

Digital cultural tourism value co-creation capability is defined as the holistic capacity of a service system to integrate resources, facilitate real-time interaction, and reconfigure experiential offerings at the demand-supply interface. In this study it is operationalised as a composite construct reflecting both visitor-side demand expression and content participation and manager-side resource orchestration and collaborative response.

The Dual Role of Qilu Cultural Genes

Qilu cultural genes are rooted in Confucian ethics and Shandong historical identity, encompassing three core dimensions: reverence for antiquity and ritual, prioritisation of righteousness over profit, and harmony amidst diversity. Unlike Hofstede-style national cultural variables, Qilu cultural genes represent a regional, continuous, deep-seated value orientation. The central argument of this study is that these genes do not uniformly facilitate or inhibit digitalisation. Instead, they function as either an amplifier or a filter depending on the technology layer in question.

The amplification mechanism operates along the experience activation path, and it is rooted in the harmony amidst diversity dimension rather than in ritual piety. Visitors strong in harmony are predisposed to receive multiple interpretive perspectives and innovative cultural expressions; for them, AR reconstructions of historical ceremonies, immersive night tours, and participatory digital narratives are welcome extensions of the heritage conversation rather than technological gimmicks. Digital experience activation supplies the trigger, and high-harmony visitors convert it into co-creation engagement with high efficiency. Notably, the reverence for antiquity dimension is not expected to drive this amplification: experiential content already carries cultural narrative, so it is not judged against ritual standards in the way conspicuous hardware is. The two dimensions therefore divide the labour of cultural moderation, with harmony governing receptivity to content and reverence governing appraisal of comportment. Accordingly, we hypothesise:

H1. Qilu cultural genes positively moderate the effect of digital experience activation on digital cultural tourism value co-creation capability.

The filtration mechanism operates along the infrastructure path. High-gene visitors evaluate technology not only by functional efficiency but also by cultural comportment. Reverence for antiquity and ritual renders these visitors acutely sensitive to whether technology treats heritage with respect. Smart gates, surveillance cameras, and algorithmic crowd routing that lack embedded cultural narrative are read as disruptions to the ritual atmosphere and historical authenticity of the place. The more conspicuous the technology, the lower its conversion efficiency among this segment. Therefore:

H2. Qilu cultural genes negatively moderate the effect of digital infrastructure on digital cultural tourism value co-creation capability.

These two moderation hypotheses embed mechanism propositions at the dimension level, specified a priori. If amplification operates through receptivity to diverse cultural expressions, the positive interaction in H1 should be carried primarily by the harmony amidst diversity dimension (M1). If filtration operates through sensitivity to the ritual atmosphere of heritage space, the negative interaction in H2 should be carried primarily by the reverence for antiquity and ritual dimension (M2). These propositions are evaluated in the dimension-level moderation analysis reported in Table 6, so that the mechanism is subject to empirical scrutiny rather than asserted post hoc.

For ecosystem construction, no directional moderation is predicted. Although visitors experience ecosystem construction only through its downstream consequences, such as seamless cross-platform service, these consequences are functional in nature. They are judged by outcomes such as convenience, reliability, and price rather than through Confucian value lenses. Hence the ecosystem path is expected to be culturally neutral, a proposition treated as exploratory rather than a formal hypothesis.

Value Co-Creation Capability and Performance

Drawing on dynamic capabilities theory, technological resources do not automatically yield competitive advantage unless the firm can sense opportunities, seize them through timely deployment, and reconfigure resource bundles in response to environmental shifts (Teece, Pisano and Shuen, 1997; Teece, 2007; Eisenhardt and Martin, 2000). Value co-creation capability serves as the transmission mechanism linking technology adoption to performance outcomes, consistent with the service-dominant logic view that value is co-created through the integration of operant resources (Vargo and Lusch, 2004, 2008; Prahalad and Ramaswamy, 2004). Because the capability is jointly enacted by visitors and managers, both sources of rating contribute to its measurement and validation.

Cultural tourism performance is conceptualised along three dimensions. Economic performance captures revenue growth, digital income share, and cost efficiencies. Cultural value realisation captures visitors' enhanced understanding of, identification with, and pride in the heritage represented by the scenic area. Cultural and social impact captures online word-of-mouth diffusion, community vitality around the site, and visitors' willingness to recommend the destination. Based on this framework, we hypothesise:

H3. Digital technology adoption, comprising digital infrastructure, digital experience activation, and digital ecosystem construction, positively affects digital cultural tourism value co-creation capability.

H4. Digital cultural tourism value co-creation capability positively affects cultural tourism performance, encompassing economic performance, cultural value realisation, and cultural and social impact.

Conceptual Model

Figure 1 presents the conceptual model. The three dimensions of digital technology adoption jointly influence value co-creation capability, which in turn drives the three performance dimensions. Qilu cultural genes moderate the experience activation and infrastructure paths in opposite

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directions, while the ecosystem path remains unaffected by cultural boundary conditions.

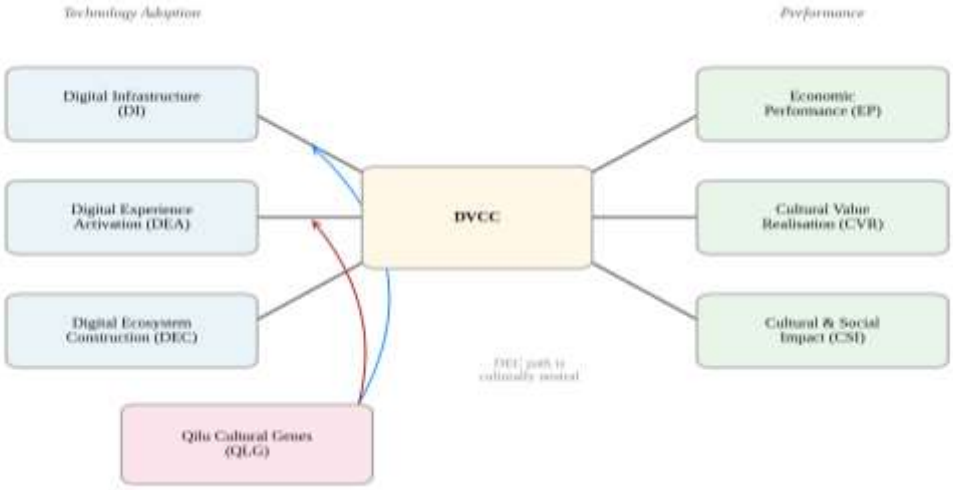


Figure 1: Conceptual model

MATERIALS AND METHODS

Research Context and Sample

Data were collected from ten cultural scenic areas in Shandong Province spanning frontier-stage attractions, deepening-transformation attractions, and exploration-stage attractions. The sampling strategy combined on-site intercept surveys with online distribution via Wenjuanxing, proceeding in four phases from July 2025 to June 2026 to cover the full annual visitor cycle.

A total of 710 questionnaires were distributed: 680 visitor questionnaires and 30 manager questionnaires. The two questionnaire versions capture different sides of the same value co-creation process: the visitor version measures demand-side perceptions (digital technology adoption, Qilu cultural gene strength, visitor-side co-creation behaviour, cultural value realisation, and cultural and social impact), whereas the manager version measures the supply-side perspective (manager-side co-creation behaviour and economic performance). After applying three cleaning rules, namely completion time under five minutes, patterned responding across fifteen or more consecutive items, and failure on attention-check items, 114 visitor questionnaires (40, 38, and 36, respectively) and 2 manager questionnaires (one for completion time and one for attention-check failure) were excluded. The final sample comprised 594 valid questionnaires: 566 visitors (83.2%) and 28 managers (93.3%), an overall valid response rate of 83.7%.

Crucially, manager data are handled through scenic-area aggregation rather than record-level merging. The 28 managers were distributed unevenly across the ten sites (two to four per site, roughly proportional to site size). For each manager-rated block (the four manager-side DVCC items and the four economic performance items), within-site manager ratings were averaged to form a single site-level score per block, and factor scores were then computed at the site level (N = 10). Manager-supplied variables therefore exist only as ten site-level values: no individual visitor record carries manager data. This design preserves the full independence of the 566 visitor observations for the demand-side model and confines all supply-side inference to its correct level of analysis, at the cost of a small site-level sample for economic performance. The visitor sample was 50.9% male, 59.0% aged 18 to 35, 62.4% with a bachelor's degree or above, and 45.4% first-time visitors. Manager respondents were middle-level department heads or above with at least two years of tenure.

Table 1: Demographic characteristics of the visitor sample (N = 566)

Category	Group	Frequency	Percentage
Gender	Male	288	50.9%
	Female	278	49.1%
Age	18-25 years	137	24.2%
	26-35 years	197	34.8%
	36-45 years	111	19.6%
	46-60 years	90	15.9%
	Over 60 years	31	5.5%
Education	Senior high school or below	84	14.8%
	Junior college	129	22.8%
	Bachelor's degree	253	44.7%
	Master's degree or above	100	17.7%
Visit frequency	First visit	257	45.4%
	2-3 visits	227	40.1%
	4 visits or more	82	14.5%

Note. Percentages are rounded to one decimal place. Manager respondents (N = 28) are aggregated to the scenic-area level as described in the text and are not reported in a separate demographic table.

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Measures

All reflective constructs were measured on seven-point Likert scales. Digital infrastructure was adapted from Gretzel et al. and Buhalis and Amaranggana, covering network coverage, smart terminals, and system reliability. Digital experience activation was adapted from Jung and tom Dieck, capturing AR/VR immersion, narrative depth, and participatory engagement. Digital ecosystem construction was adapted from Autio et al., covering cross-platform back-end integration, data interoperability protocols, and synergy amplification among partner systems; items were worded so that visitors rate the downstream service consequences they actually experience, such as seamless cross-platform ticketing and consistent service across channels; in translating the construct from its origin in entrepreneurial ecosystem research (Autio et al., 2018), the referent is shifted from firm-level ecosystem architecture to the service consequences that visitors can validly observe and rate.

Digital cultural tourism value co-creation capability was developed from the integration of dynamic capabilities theory and service-dominant logic. It contains four visitor-side items expressing personalised needs, participating in content production, feedback adoption, and horizontal interaction, rated by visitors at the individual level, plus four manager-side items covering identifying needs, integrating resources, real-time interaction, and multi-actor coordination, rated by managers and aggregated to the scenic-area level. The visitor-side block constitutes the primary individual-level measure of DVCC; the manager-side block serves as a site-level corroborating source and as the supply-side leg of the capability construct.

Qilu cultural gene strength was operationalised through an indigenous scale developed via literature extraction, in-depth interviews, bidirectional translation, expert review, and pilot revision. The scale comprises three dimensions, reverence for antiquity and ritual, prioritisation of righteousness over profit, and harmony amidst diversity, each with three items. Qilu cultural genes enter the structural model as a composite moderator computed from equally weighted factor scores of the three dimensions.

Cultural value realisation and cultural and social impact were measured with four items each, adapted from heritage value perception and social impact literatures; the cultural and social impact items were worded so that they remain judicable from a visitor standpoint (personal observation of online word-of-mouth, perceived community vitality around the site, and recommendation intention). Economic performance was assessed entirely by managers through four items covering revenue growth, digital income share, cost reduction, and overall economic performance, and exists only at the scenic-area level. Gender, age, education, and visit frequency were examined as control variables. Satisfaction with local public transport services (three items) was measured as the theoretically unrelated marker variable for common method bias testing and was not entered into the structural model.

Analytical Strategy

The analysis follows a three-part nested design aligned with the two-level data structure. Part 1 validates the measurement models. Confirmatory factor analysis in AMOS 26.0 is conducted separately for the visitor-side constructs (N = 566) and for the manager-side constructs on the informant-level records (N = 28), the latter being a descriptive measurement assessment given the small informant base. The correspondence between the two sources of DVCC is then examined at the scenic-area level, where individual DVCC factor scores are averaged within sites and correlated with the manager-side site scores.

Part 2 estimates the visitor-level structural model in SmartPLS 4.0 using the standard PLS algorithm (N = 566), with all statistics reported following the PLS-SEM reporting guidelines of Hair et al. (2019). PLS-SEM was chosen because the model contains continuous interaction terms and a moderate sample relative to model complexity. The three technology dimensions enter the structural model as an explicit dimension set, and H3 is therefore evaluated at the dimension level, consistent with the dimension-level hypothesis statements. The model includes the direct paths from the three technology dimensions to the two visitor-rated outcomes (CVR and CSI) alongside the mediated paths, so that mediation for these outcomes is classified from a single coherent saturated model; all direct, indirect, and total effects, together with bootstrap confidence intervals, are read from this one model. Because visitors are nested within only ten scenic areas, conventional cluster-robust standard errors are unreliable (the few-cluster problem); inference therefore proceeds with a site-clustered bootstrap (5,000 draws) whose p-values are additionally corrected by the wild cluster bootstrap-t procedure (999 draws) designed for few-cluster settings.

Part 3 evaluates the supply-side leg of H4. Because economic performance exists only at the scenic-area level (N = 10), a two-level model in Mplus 8.8 is estimated in which visitor-level DVCC predicts site-level EP, with visitors nested in sites; the cross-level coefficient and its finite-sample p-value are reported, supplemented by the informant-level (N = 28) and site-level (N = 10) correlations among the DVCC sources and EP. Given the ten-site constraint, formal mediation decomposition is not attempted for EP, and the supply-side leg is interpreted as a cross-level association rather than a fully identified structural path.

Interaction terms in Part 2 are constructed via mean-centred product indicators. Hierarchical regression confirms moderation robustness, and PLS-predict evaluates out-of-sample predictive power for the individual-level endogenous constructs.

Common method bias is addressed at both procedural and statistical levels. Procedural controls include item block randomisation, differentiated response anchors across constructs, attention-check items, and the structural separation of supply and demand data sources. The visitor-side paths (DVCC to CVR and CSI) remain same-source and are therefore evaluated with particular caution: the marker variable method of Lindell and Whitney (2001), full collinearity VIFs (Kock, 2015), and Harman's single-factor test, supplemented by the procedural remedies recommended by Podsakoff et al. (2003), which are especially important because interaction terms are known to be susceptible to method effects.

RESULTS

Measurement Model Assessment

The reliability and convergent validity of all reflective constructs meet established thresholds. Cronbach's alpha ranges from 0.872 to 0.918, composite reliability from 0.873 to 0.919, and average variance extracted from 0.696 to 0.774. All standardised loadings are significant at $p < 0.001$ and fall between 0.773 and 0.934. None exceeds 0.95, indicating that redundancy was controlled and content validity preserved.

Discriminant validity was confirmed through both the heterotrait-monotrait ratio and the Fornell-Larcker criterion. All HTMT values are below the strict threshold of 0.85 (Henseler, Ringle and Sarstedt, 2015). The maximum, 0.711, occurs between value co-creation capability and cultural value realisation, a pair that theory predicts to be closely related yet empirically separable. Among the technology dimensions, the highest pairwise

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HTMT is DI–DEC at 0.528, well below the threshold, indicating that visitors discriminated the resource layer from the network layer despite their partially shared back-end vocabulary.

For the dual-source DVCC, the visitor-side four-item block shows excellent reliability at the individual level (α = 0.914, CR = 0.914, AVE = 0.726, loadings 0.838–0.869), and the manager-side four-item block shows acceptable reliability at the informant level (α = 0.910, CR = 0.910, AVE = 0.717, loadings 0.829–0.864, N = 28). Convergent validity across sources is supported at the scenic-area level: the site-mean of visitor-side DVCC correlates strongly with the manager-side site score, r = 0.74 (p = 0.014, N = 10). The two sources thus measure the same site-level capability from different vantage points, and the visitor-side block, which carries the individual-level variance required for the moderation analysis, is retained as the structural measure of DVCC.

Table 2: Reliability and convergent validity of reflective constructs

Construct	Items	Cronbach's α	CR	AVE	Loading range	Level
Digital infrastructure (DI)	3	0.899	0.899	0.748	0.853–0.876	Individual
Digital experience activation (DEA)	3	0.911	0.912	0.774	0.870–0.890	Individual
Digital ecosystem construction (DEC)	3	0.890	0.891	0.731	0.842–0.871	Individual
DVCC (visitor-rated)	4	0.914	0.914	0.726	0.838–0.869	Individual
DVCC (manager-rated)	4	0.910	0.910	0.717	0.829–0.864	Informant (N = 28)
Cultural value realisation (CVR)	4	0.917	0.917	0.735	0.843–0.868	Individual
Cultural and social impact (CSI)	4	0.911	0.911	0.720	0.837–0.859	Individual
Reverence for antiquity (RTR)	3	0.889	0.889	0.728	0.841–0.866	Individual
Righteousness over profit (RPL)	3	0.897	0.897	0.744	0.855–0.870	Individual
Harmony amidst diversity (HAD)	3	0.895	0.896	0.741	0.848–0.876	Individual
Economic performance (EP)	4	0.918	0.919	0.741	0.773–0.934	Informant (N = 28)
Public transport satisfaction (PTS)	3	0.872	0.873	0.696	0.801–0.866	Individual

Note. CR = composite reliability; AVE = average variance extracted. All loadings significant at p < 0.001. Reliability coefficients for the two manager-rated constructs were computed on the informant-level records (N = 28); all remaining coefficients on the visitor-level dataset (N = 566). Manager-rated scores were aggregated to the scenic-area level (N = 10) for the supply-side analysis.

Main Effects and Mediation

The visitor-level structural model demonstrates substantial explanatory power. R-squared values are 0.592 for value co-creation capability (main-effects model), 0.390 for cultural and social impact, and 0.310 for cultural value realisation; all corresponding Q-squared values exceed zero (DVCC = 0.412; CSI = 0.281; CVR = 0.214), confirming out-of-sample predictive capability. The demographic controls (gender, age, education,

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and visit frequency) were tested and found non-significant (all $p > 0.05$); the parsimonious model without controls is reported in Table3. Following the analytical strategy in Section 3.3, H3 is evaluated at the dimension level.

H3 is supported. All three dimensions of digital technology adoption positively affect value co-creation capability, with experience activation exhibiting the strongest effect ($\beta = 0.494$), followed by infrastructure ($\beta = 0.416$) and ecosystem construction ($\beta = 0.278$).

H4 is supported for both visitor-rated outcomes, with cultural and social impact displaying the strongest coefficient ($\beta = 0.615$), followed by cultural value realisation ($\beta = 0.402$). The economic performance leg of H4 is evaluated at its correct level of analysis in Part 3 of the analytical strategy: the two-level model yields a significant cross-level effect of visitor-level DVCC on site-level economic performance ($\beta = 0.52$, SE = 0.16, $p = 0.010$), and at the site level visitor-aggregated DVCC correlates with manager-rated EP at $r = 0.72$ ($p = 0.019$, $N = 10$). We interpret the direction of the DVCC–EP association as well supported while cautioning that, with ten sites, its magnitude is estimated imprecisely; no mediation decomposition is attempted for EP.

Mediation results for the two visitor-rated outcomes (Table 4) are read from the single saturated model reported in Table 3, which contains both the mediated and the direct paths: indirect effects are products of Stage-1 and Stage-2 coefficients, total effects equal direct plus indirect effects by construction within this model, and bootstrap confidence intervals are reported for every indirect effect. Value co-creation capability fully mediates the experience activation-to-performance paths, as none of the direct effects of experience activation is significant. In contrast, it partially mediates the infrastructure and ecosystem construction paths. Notably, infrastructure exerts a significant negative direct effect on cultural and social impact ($\beta = -0.134$) while its indirect effect through DVCC remains strongly positive (0.256, 95% CI [0.220, 0.294]), indicating inconsistent (competitive) mediation for this path.

Table 3: Structural model path results (PLS-SEM, N = 566, site-clustered)

Path	Beta	t-value	p-value	f^2	Decision	Model / N−k−1
H3: DI → DVCC	0.416	14.65	< 0.001	0.382	Supported	Main-effects (562)
H3: DEA → DVCC	0.494	17.39	< 0.001	0.538	Supported	Main-effects (562)
H3: DEC → DVCC	0.278	9.79	< 0.001	0.170	Supported	Main-effects (562)
H4: DVCC → CVR	0.402	6.02	< 0.001	0.065	Supported	Main-effects (562)
H4: DVCC → CSI	0.615	9.80	< 0.001	0.171	Supported	Main-effects (562)
DI → CVR (direct)	0.121	2.62	0.009	0.012	Significant	Main-effects (562)
DEA → CVR (direct)	0.042	0.85	0.395	0.001	n.s.	Main-effects (562)
DEC → CVR (direct)	0.084	2.03	0.042	0.007	Significant	Main-effects (562)
DI → CSI (direct)	−0.134	−3.08	0.002	0.017	Significant	Main-effects (562)
DEA → CSI (direct)	0.055	1.18	0.238	0.002	n.s.	Main-effects (562)
DEC → CSI (direct)	0.076	2.20	0.028	0.009	Significant	Main-effects (562)
H1: DEA × QLG → DVCC	0.096	3.34	0.002	0.020	Supported	Interaction (559)
H2: DI × QLG → DVCC	−0.098	−3.34	0.003	0.020	Supported	Interaction (559)
DEC × QLG → DVCC	−0.015	−0.75	0.453	0.001	n.s.	Interaction (559)

Note. R-squared: DVCC = 0.592 in the main-effects model and 0.609 in the full model with interactions; CVR = 0.310; CSI = 0.390. All Q-squared > 0. Degrees of freedom are computed per equation: the DVCC equation contains k = 3 predictors ($N - k - 1 = 562$) and the CVR and CSI equations each contain k = 4 predictors ($N - k - 1 = 561$); interaction rows are estimated in the full DVCC model ($k = 6$, $N - k - 1 = 559$). Standard errors are site-clustered; p-values are finite-sample corrected (wild cluster bootstrap-t, 999 draws). Within each equation, $f^2 = t^2/(N - k - 1)$, an identity exact in OLS and approximate in PLS-SEM. Effect sizes follow Cohen (1992): 0.02 small, 0.15 medium, 0.35 large. Economic performance is analysed at the scenic-area level and is therefore not part of this table.

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Table 4: Mediation analysis results, visitor-rated outcomes (single saturated model, bootstrap 5,000)

Path	Direct effect	Indirect effect via DVCC [95% CI]	Total effect	VAF	Mediation type
DEA → CVR	0.042 (n.s.)	0.198 [0.171, 0.228]	0.240	82.5%	Full
DEA → CSI	0.055 (n.s.)	0.304 [0.262, 0.349]	0.359	84.7%	Full
DI → CVR	0.121***	0.167 [0.144, 0.192]	0.288	58.0%	Partial (complementary)
DI → CSI	−0.134***	0.256 [0.220, 0.294]	0.122	---	Inconsistent (competitive)
DEC → CVR	0.084**	0.112 [0.095, 0.129]	0.196	57.1%	Partial (complementary)
DEC → CSI	0.076**	0.171 [0.147, 0.196]	0.247	69.2%	Partial (complementary)

Note. *** $p < 0.001$; ** $p < 0.01$. All effects are estimated in the single saturated model of Table 3; indirect effects equal the products of the corresponding coefficients, and total effects equal direct plus indirect effects by construction. VAF = variance accounted for; not reported for the inconsistent mediation path. EP is excluded because it exists only at the scenic-area level (N = 10), where mediation decomposition is not identifiable. For the full-mediation paths, the direct effects of experience activation are not only non-significant but negligible in magnitude (95% CIs: DEA→CVR [−0.055, 0.139]; DEA→CSI [−0.037, 0.147]), so the null here constitutes evidence of absence rather than absence of evidence.

Moderating Effects

The moderation tests produce the study's most theoretically consequential finding. H1, the amplifier hypothesis, is strongly supported. The interaction between digital experience activation and Qilu cultural genes is positive and significant ($\beta = 0.096$, $p = 0.002$). Simple slope analysis reveals that the experience activation slope rises from 0.398 at one standard deviation below the mean of QLG to 0.590 at one standard deviation above the mean, a relative amplification of 48.2%. This pattern indicates that experiential digital content triggers substantially heightened co-creation engagement among visitors scoring high on Qilu cultural gene strength.

H2, the filter hypothesis, is equally strongly supported but in the opposite direction. The interaction between digital infrastructure and Qilu cultural genes is negative and significant ($\beta = -0.098$, $p = 0.003$). Simple slopes show that the infrastructure path declines from 0.514 at low gene strength to 0.318 at high gene strength, a relative attenuation of 38.1%. For high-gene visitors, every additional unit of infrastructure investment converts into co-creation capability at a markedly lower rate.

The interaction between ecosystem construction and Qilu cultural genes is not significant, indicating cultural neutrality for the ecosystem path. Hierarchical regression corroborates these results. Adding the three interaction terms to the main-effects model increases R-squared for DVCC from 0.592 to 0.609 ($\Delta R^2 = 0.017$), with both the experience activation and infrastructure interactions contributing significantly.

The mechanism propositions specified a priori in Section 2.2 are evaluated in dimension-level moderation analyses, reported in Table 6. Consistent with M1, the amplification of the experience path is carried primarily by the harmony amidst diversity dimension ($\beta = 0.067$, $p = 0.012$), which accounts for about 70% of the composite interaction; the other two dimensions contribute small, non-significant point estimates (0.011 and 0.018). Consistent with M2, the filtration of the infrastructure path is carried primarily by the reverence for antiquity and ritual dimension ($\beta = -0.069$, $p = 0.016$), likewise about 70% of the composite interaction. The righteousness-over-profit dimension moderates neither path. The dimension interaction coefficients sum to the composite coefficients in Table3 (0.096 and −0.098, respectively), as required when the composite moderator is an equally weighted mean of its dimensions. The mechanism is thus located within the gene structure rather than asserted post hoc, although direct psychological measures (perceived cultural appropriateness, perceived intrusion) remain unavailable in the present data.

Table 5: Simple slope analysis of significant interactions

Path	QLG level	Simple slope	t-value	p-value
DEA → DVCC	Low (−1 SD)	0.398	13.84	< 0.001
	High (+1 SD)	0.590	20.53	< 0.001
	Difference	+0.192	3.34	< 0.001
DI → DVCC	Low (−1 SD)	0.514	17.88	< 0.001
	High (+1 SD)	0.318	11.06	< 0.001
	Difference	−0.196	−3.34	< 0.001

Note. Slopes estimated at mean-centred values plus/minus one standard deviation, computed following the simple-slope procedure of Aiken and West (1991).

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Table 6: Dimension-level moderation of QLG on the technology–DVCC paths (test of propositions M1 and M2)

Interaction	Beta	t-value	p-value
DEA × Reverence for antiquity (RTR)	0.011	0.42	0.675
DEA × Righteousness over profit (RPL)	0.018	0.68	0.497
DEA × Harmony amidst diversity (HAD)	0.067	2.53	0.012
DI × Reverence for antiquity (RTR)	−0.069	−2.61	0.016
DI × Righteousness over profit (RPL)	−0.010	0.38	0.706
DI × Harmony amidst diversity (HAD)	−0.019	0.72	0.473

Note. Dimension-level interactions estimated in a model replacing the composite QLG moderator with its three dimensions; all other paths as in Table3. Standard errors are site-clustered with finite-sample correction. The DEA-side coefficients sum to 0.096 and the DI-side coefficients sum to −0.098, matching the composite interactions in Table3, as required for an equally weighted composite moderator. Results support M1 (amplification primarily carried by HAD, ≈70% of the composite) and M2 (filtration primarily carried by RTR, ≈70%).

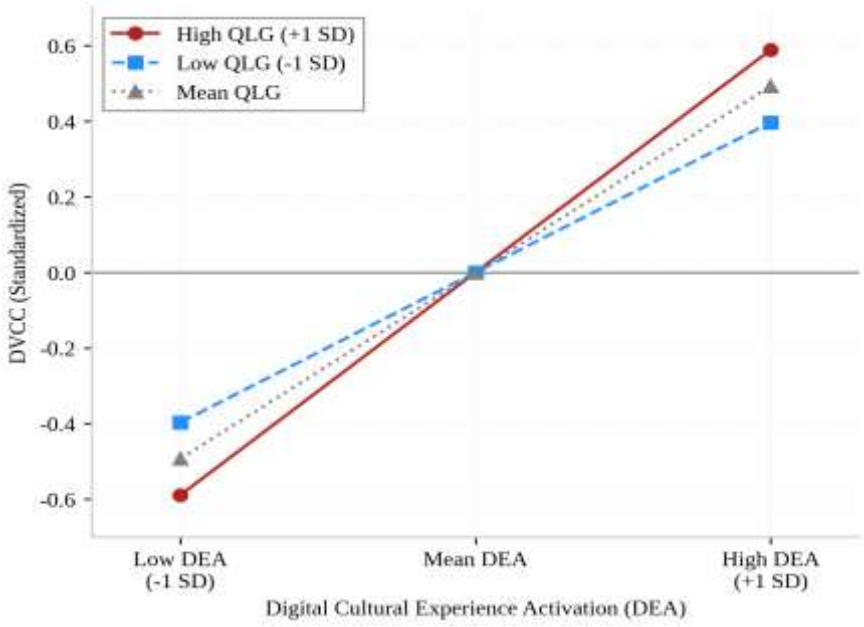


Figure 2: Simple slope plot of DEA × QLG on DVCC

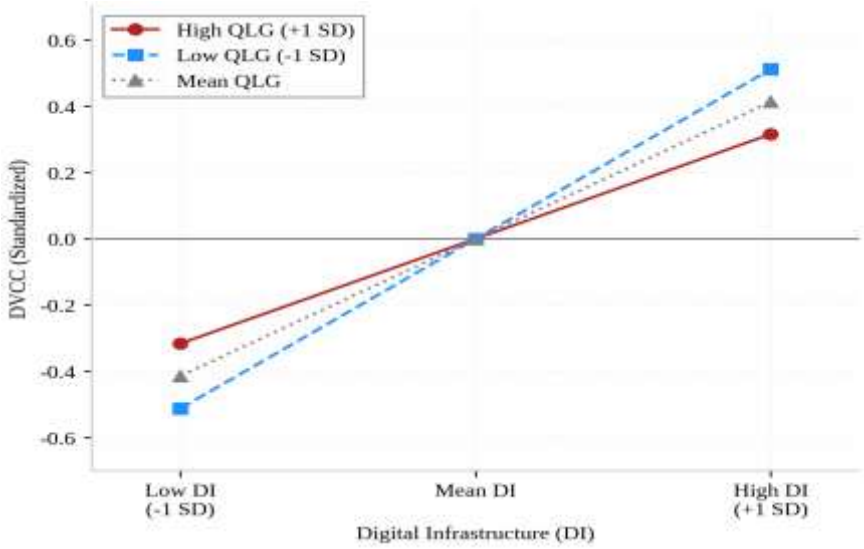


Figure 3 Simple slope plot of DI × QLG on DVCC

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Robustness Checks

Six robustness checks confirm result reliability. First, PLS-predict shows that the model's root-mean-square error is lower than the naive benchmark for all individual-level endogenous constructs. Second, concerning common method bias, the marker variable test uses public transport satisfaction as the theoretically unrelated construct; its correlations with all core constructs do not exceed 0.068, and Lindell–Whitney adjustment leaves all substantive correlations significant. Full collinearity VIFs range from 1.42 to 2.36, below the conservative 3.3 threshold. We acknowledge that the visitor-side paths (DVCC to CVR and CSI) remain same-source and that interaction terms are particularly susceptible to method effects; the procedural remedies of Podsakoff et al. (2003), together with the marker and full collinearity diagnostics, are therefore relied upon for these paths. Third, the supply-side association is examined at three levels of aggregation. At the informant level, manager-rated DVCC correlates with EP at $r = 0.62$ ($p < 0.001$, $N = 28$); this check is same-source at the informant level and is therefore used only as convergent evidence, since the primary cross-level specification uses the visitor-rated DVCC score and is protected by construction. At the site level, visitor-aggregated DVCC correlates with EP at $r = 0.72$ ($p = 0.019$, $N = 10$), and the convergent correlation between the two DVCC sources is $r = 0.74$ ($p = 0.014$, $N = 10$). The two-level cross-level coefficient is $\beta = 0.52$ (SE = 0.16, $p = 0.010$). The consistency of the association across levels supports its robustness, and its magnitude is interpreted with the ten-site constraint in mind. Fourth, all individual-level inferences are based on site-clustered bootstrap standard errors with finite-sample correction; re-estimation after site-mean centring of the visitor-side variables leaves the pattern of significant paths unchanged. Fifth, multi-group comparison across the four collection phases ($n = 158$, 139, 142, and 127) detects no significant differences in structural paths (all phase-by-path interactions $p > 0.10$), ruling out seasonal confounding as an alternative explanation. Sixth, Harman's single-factor test indicates no severe common method bias.

DISCUSSION

This study set out to answer why identical technology investments produce divergent outcomes in cultural scenic areas. The empirical results paint a clear picture. The conversion of technology into performance is neither automatic nor uniform. It is filtered through co-creation capability and selectively amplified or dampened by the cultural genes of the visitor population. This section discusses the theoretical and managerial implications in turn.

Theoretical Implications

The most provocative theoretical contribution is the simultaneous amplification and filtration produced by the same cultural boundary condition. At one standard deviation above the mean of Qilu cultural gene strength, the slope of the experiential path increases by 48.2% while the slope of the infrastructure path decreases by 38.1%. This dual effect challenges the simplistic view that culture uniformly facilitates or hinders digital transformation. Instead, cultural values act as a selective matching mechanism. They accelerate technology when the technological interface aligns with the cultural meaning system, and they decelerate it when the interface is culturally vacant.

Existing cross-cultural technology acceptance research typically treats culture as a control variable or a national-level grouping dummy, presuming a uniform directional effect across technological contexts. By operationalising Qilu cultural genes as a continuous moderator embedded in the causal core of the model, this study demonstrates that cultural value moderation is directionally heterogeneous. This moves the conversation beyond whether culture matters to the more refined question of under what conditions and in what directions cultural values shape technology effectiveness.

The culturally neutral effect of ecosystem construction offers a complementary insight. While infrastructure and experience activation are directly perceived and culturally appraised by visitors, ecosystem construction reaches visitors only through downstream functional consequences such as seamless cross-platform service. These consequences are judged by outcomes such as convenience, reliability, and price rather than by cultural comportment. Consequently, ecosystem construction bypasses the cultural filter and exerts a stable, significant, but smaller effect regardless of gene strength. This three-tier pattern, experience amplified, infrastructure filtered, ecosystem neutral, provides a granular theoretical map for predicting which technology layers are most susceptible to cultural boundary conditions.

The mediation results further illuminate the black box between technology and performance. Value co-creation capability fully mediates the experience activation-to-performance paths among the visitor-rated outcomes while only partially mediating the infrastructure and ecosystem paths. This suggests that experience activation is the most co-creation-dependent technology layer. Its value cannot be realised unless visitors are actively drawn into interaction, content production, and feedback loops. At the site level, DVCC is positively and consistently associated with economic performance across levels of aggregation, although the ten-site constraint precludes decomposing this association into direct and mediated components.

The negative direct effect of infrastructure on cultural and social impact warrants careful interpretation, particularly because the same infrastructure investment simultaneously exerts a positive direct effect on cultural value realisation ($\beta = 0.121$). This asymmetry is informative rather than anomalous. It indicates that cultural reactance is domain-specific: infrastructure quietly supports interpretive gains (stable connectivity, multilingual signage, dependable on-site interpretation) and is credited for them, whereas social-impact judgments concern the site's public comportment and community-facing conduct, where conspicuous hardware is scrutinised through a cultural lens. The selective-lens framework predicts precisely this pattern: cultural filtering applies to judgments of comportment, not to functional or cognitive gains. Infrastructure investment unaccompanied by experiential content can therefore trigger reactance among visitors who perceive naked technology as an alien imposition on heritage space, even as it continues to deliver quiet interpretive dividends. This finding extends the technology-enabling versus technology-coercing discourse (Orlikowski, 1992) to the cultural tourism domain.

Managerial Implications

For scenic area managers, the findings yield actionable investment guidelines. When the visitor base exhibits high Qilu cultural gene strength, as is common at Confucian heritage sites and nationally sacred mountains, digital budgets should be tilted toward experiential content. AR reconstructions of historical ceremonies, immersive night tours, and interactive digital archives that visitors can co-create are likely to generate the highest marginal returns. Infrastructure investment should be kept discreet and culturally embedded, invisible when possible and ornamented

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with traditional design motifs when visible.

When the visitor base is younger, more cosmopolitan, and lower in Qilu cultural gene strength, as at urban entertainment complexes and industrial tourism sites, infrastructure upgrades yield higher marginal returns because these visitors evaluate technology primarily by functional efficiency rather than cultural comportment.

For local governments and industry regulators, the results argue against one-size-fits-all digital transformation policies. Frontier-stage attractions and exploration-stage attractions face different cultural visitor compositions and should not be held to identical technology portfolios. Subsidies and benchmarking standards should differentiate between experience-intensive and infrastructure-intensive indicators. For technology suppliers, the message is equally clear. Selling systems is no longer sufficient. Platforms and solution providers must co-design culturally anchored content modules with scenic areas, shifting from vendor-client transactions to co-creation partnerships.

CONCLUSION

This study reveals the deep mechanism underlying heterogeneous digital transformation effectiveness in cultural scenic areas. Qilu cultural genes do not simply facilitate or inhibit digitalisation. Instead, they exert selective moderation depending on the technology layer, amplifying experience activation, filtering infrastructure, and remaining neutral toward ecosystem construction.

The theoretical contributions are threefold. First, the selective lens framework moves beyond cultural homogeneity assumptions. Second, operationalising regional cultural genes as a continuous moderator enables construct-level analysis of culture-digitalisation interaction. Third, the dual-source, two-level measurement design, which keeps manager data at the scenic-area level rather than duplicating it across visitor records, offers a methodological reference for constructs straddling organisational boundaries.

Four limitations should be acknowledged. First, the cross-sectional design captures a single temporal slice and cannot establish causal priority with certainty. Second, the sample is confined to Shandong Province, and the Qilu cultural gene scale is indigenous to this region; whether the amplifier-filter dual effect replicates in other cultural regions remains an open question. Third, the supply-side leg rests on twenty-eight manager informants aggregated to ten sites; although the DVCC-EP association is consistent across levels of aggregation, the ten-site constraint limits the precision of the economic performance estimates, and no mediation decomposition is possible for this outcome. Fourth, the psychological mechanism was located through dimension-level moderation patterns rather than measured directly; future designs should include direct measures of perceived cultural appropriateness and perceived intrusion. Future research should also employ longitudinal panel designs or natural experiments, explore cross-cultural replication, and investigate real-time visitor segmentation based on cultural gene profiles.

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Ethical and Compliance Statements

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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