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Research Article

Digital Approaches for the Protection of Inner Mongolia's Paper-Cutting Art as Intangible Cultural Heritage

Jieru Chen [1], Wan Samiati Andriana W Mohamad Daud [2*], Mohd Adzman Omar[3]

[1] Ph.D Candidate, Faculty of Art and Design, Universiti Teknologi MARA, Shah Alam, Kuala Lumpur, Malaysia
[2] Dr., Faculty of Art and Design, Universiti Teknologi MARA, Shah Alam, Kuala Lumpur, Malaysiaa
[3] Dr., Faculty of Art and Design, Universiti Teknologi MARA, Machang, Kelantan, Malaysia
* **Corresponding Author:** samiati@uitm.edu.my

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ABSTRACT

One of the key elements of the intangible cultural heritage (ICH) of China, the paper-cutting art of Inner Mongolia, is increasingly facing a threat in terms of preservation and transmission within the context of the quickly modernised society and demographic changes. Even though the use of digital technologies is promoted as a way of preserving ICH, their actual impact is not sufficiently researched. The study will analyze the consequences of adopting digital technologies on the outcomes of heritage preservation, such as digital twins, virtual/augmented reality virtual reality (VR) and aumented reality (AR), artificial intelligence (AI), blockchain, and knowledge graphs, based on the original survey data of 200 artisans and heritage institutions carried out in 2024-2025. Using the mixed-method method and regression analysis, we can find that there exists a positive statistically significant influence of digital adoption on the performance in preservation and that the increase of one unit in the index of digital adoption has a positive effect on the preservation scores by 2.41-points ($p < 0.001$). Though knowledge of digital technologies, on the one hand, is positively related to preservation, mediation analysis indicates that the relationship between digital adoption and preservation is not significantly mediated by artisans' knowledge of digital technologies, and the indirect relationship is insignificant. Further results indicate that the positive impact of digital adoption is increased with policy support. The results show that digital technologies aid in maintaining a heritage primarily through direct and ecosystem-scale effects and not through the transmission of personal knowledge. The research gives empirical data to guide the development of integrated, policy-enhanced digital policies to preserve intangible cultural heritage.

Keywords: Inner Mongolia's paper-cutting; Intangible cultural; Heritage safeguarding; Digital adoption; Immersive technologies (VR/AR); Knowledge graphs

INTRODUCTION

Context and Stakes

Paper-cutting is a culturally significant folk art in Inner Mongolia, embodying collective memory, ritual practice and aesthetic expression. Since UNESCO inscribed Chinese paper-cutting on its Representative List of Intangible Cultural Heritage in 2009, scholars and policymakers have sought ways to ensure its sustainability amidst rapid socio-economic change (Zabulis et al., 2025). The craft involves intricate scissors work to produce symmetrical figures and motifs representing nomadic life, seasonal rituals and cosmological beliefs. In Inner Mongolia's grassland communities, paper-cutting decorates homes, yurts and ceremonial garments, and functions as a medium of intergenerational transmission. However, urbanisation, ageing rural populations and the dominance of mass-produced digital media threaten this tradition (Komorowski, 2024). The number of active practitioners has declined, and younger generations often regard paper-cutting as outdated (Schrimpf et al.,

2024).

Concurrently, digital technology has emerged as both a disruptor and an enabler. UNESCO's 2003 convention encourages the use of digital documentation and transmission to safeguard intangible cultural heritage (ICH), and governments worldwide are experimenting with virtual reality (VR)/aumented reality (AR) experiences, artificial intelligence (AI)-driven reconstructions and digital twin models. International projects such as Korea's VR exhibitions of traditional music and UNESCO-Google virtual heritage tours illustrate the potential of immersive technologies to engage younger audiences and expand access (Kim et al., 2019). In the Chinese context, state policies promote the fusion of digital technology with traditional crafts to foster rural revitalisation and cultural confidence. Inner Mongolia has piloted digital archives and e-commerce platforms for handicrafts, yet systematic evaluation of their effectiveness remains limited.

Research Gap

Despite increasing scholarly attention to digital heritage, several gaps persist. First, most studies focus on built heritage or famous archaeological sites (Lian & Xie, 2024; Münster, 2019), with fewer examining intangible crafts such as paper-cutting. The limited literature on paper-cutting emphasises creative design and generative AI (e.g., diffusion LoRA models) but seldom assesses preservation outcomes (Bao et al., 2025; Dai et al., 2024). Second, existing research often evaluates single technologies (e.g., VR or AI) in isolation, leaving the synergistic effects of integrated digital solutions underexplored (Kostadimas et al., 2025; Magliocca et al., 2025). Third, previous studies emphasise user experience and technology acceptance (Hornbæk & Hertzum, 2017; Mlekus et al., 2020) without connecting digital adoption to heritage conservation effectiveness. Finally, little is known about how institutional factors (policy support, market access) and artisan knowledge mediate the relationship between digital tools and cultural outcomes, particularly in resource-constrained regions like Inner Mongolia.

Objectives and Hypotheses

This study aims to fill these gaps by examining how digital approaches contribute to the protection and revitalisation of Inner Mongolia's paper-cutting. Specifically, we address three research questions: (1) To what extent does digital adoption by artisans and heritage institutions enhance preservation outcomes? (2) Does artisans' knowledge of digital technologies mediate this relationship? (3) How do policy support and market integration moderate the impact of digital adoption? Grounded in the literature and theoretical frameworks (D Macredie & Mijinyawa, 2011; Liu et al., 2009; Zhao & Liu, 2024), we hypothesise:

H1: Higher levels of digital adoption are positively associated with heritage preservation outcomes.

H2: Artisans' digital knowledge mediates the relationship between digital adoption and preservation.

H3: Policy support amplifies the positive effect of digital adoption on preservation outcomes.

Although the earlier literature indicates that digital knowledge mediates, we consider H2 as an empirically verifiable hypothesis, as opposed to a postulated process. With conflicting evidence in the digital heritage context, it is possible that the mediation impact of knowledge is exploratory and might not be applicable in every context.

Contributions: This paper offers several contributions. Empirically, it is among the first to assemble micro-level data on digital adoption and heritage preservation for Inner Mongolia's paper-cutting, using a novel survey and digital log indicators. Methodologically, it integrates multiple digital technologies digital twins, VR/AR, AI, blockchain and knowledge graphs, and tests their combined impact using regression, mediation analysis, heterogeneity tests and placebo checks. Conceptually, it proposes a culture-technology-community framework synthesising insights from ICH protection, digital twin ontologyand social media dissemination (Niccolucci & Felicetti, 2024). Policy-wise, it offers actionable recommendations on training, platform design, intellectual property protection and community engagement. By situating Inner Mongolia's craft within global debates on digital heritage, the study aligns with Herança's mission to explore intersections of history, heritage and culture.

Roadmap

The remainder of the paper proceeds as follows. Section 2 synthesises recent literature on digital ICH preservation, highlighting advances in digital twin platforms, VR/AR, AI, blockchain and knowledge graphs. Section 3 details the methodology, including data collection, variable construction, econometric modelling and diagnostic tests. Section 4 presents results, encompassing descriptive statistics, baseline regressions, robustness checks, heterogeneity analysis, mediation tests and sensitivity analyses, accompanied by six tables and four figures. Section 5 discusses findings in light of the literature and explores policy implications, limitations and future research. Section 6 concludes with key takeaways and contributions to academic and practitioner communities.

LITERATURE REVIEW

Digital Twins and 3D Visualization

Digital twin technology refers to virtual representations of physical objects or processes, updated via real-time data and capable of simulating behaviour (Qi et al., 2021). Heritage scholars have extended this concept to intangible crafts by capturing structural attributes, process sequences and cultural narratives. In a 2024 study, Li et al. (2024) developed a digital twin platform for Yangxin cloth paste, combining photogrammetry, VR and narrative documents. They defined a heritage digital twin (HDT) as a digital representation of tangible and intangible heritage integrating models, VR/AR, narratives and documents (Alrihani, 2022; Luther et al., 2023). The platform enabled artisans to visualise production steps, interact with virtual objects and manage transactions, thereby stimulating interest and safeguarding traditional skills. Similarly, (L. Li et al., 2025) applied 3D visualisation to design ICH products, using entropy evaluation to assess consumer engagement. Products designed with 3D visualisation attained click volumes of 5,200-5,700 and forwarding volumes of 2,000-2,400, outperforming non-digital designs. Camba et al. (2014) argued that 3D modelling captures material and morphological details, facilitates feedback between designers and clients, and enhances customer satisfaction. These findings suggest that digital twins and 3D visualisation can rejuvenate crafts by preserving procedural knowledge and enabling innovative designs.

However, limitations remain. Existing HDT frameworks primarily focus on tangible objects and seldom incorporate real-time sensor data or reactive behaviour, prompting researchers to propose extended ontologies. For example, (Mazzetto, 2024) introduced a reactive digital twin ontology that integrates sensors and actuators to allow dynamic interactions between heritage assets and digital models. Although promising, applications to paper-cutting are scarce, leaving questions about how such models can capture the intangible skills and cultural symbolism of this craft.

Virtual and Augmented Reality (VR/AR)

Immersive technologies, including VR and AR, provide multisensory experiences that transcend temporal and spatial constraints. Farella (2025) highlights in Art and Design constructed a VR system combining multimodal data acquisition (laser scanning, photogrammetry, spectral analysis), a generative adversarial network for digital twin restoration and a VR display. This system achieved high texture matching for Dunhuang murals and increased user retention by 45 % (Sun et al., 2024) . Another study by (Yu et al., 2024) examined the digital transformation of dynamic exhibits along the Grand Canal. By integrating AR-VR interactive systems, multimedia displays, interactive narration and workshops, the authors enhanced visitor experience and provided design solutions for dynamic ICH exhibitions (Li et al., 2023). VR/AR also support remote participation; for example, UNESCO-Google's virtual heritage tours enable global audiences to experience heritage sites (Siddiqui et al., 2022).

Yet, research reveals tensions between immersion and authenticity. Yan et al. (2025) found that digital dissemination indicators are shifting from technology-oriented metrics to authenticity and integrity of cultural connotation. Yi et al., (2025) employed Affective Events Theory to analyse how visual and auditory experiences influence dissemination behaviour; they showed that affective responses mediate the relationship between digital experiences and sharing behaviour, and that cultural identity moderates this effect. These studies underscore the importance of designing immersive experiences that respect cultural integrity and foster emotional connection.

Artificial Intelligence and Generative Models

AI has been adopted to automate craft design, reconstruct degraded heritage and personalise experiences. Dai et al. (2024) used the Analytic Hierarchy Process to identify factors influencing paper-cutting heritage and applied a diffusion Low-Rank Adaptation (LoRA) model to generate novel patterns. Their evaluation revealed that AI-generated designs improved patterns' richness and appeal, offering a scalable solution for creative innovation. Nonetheless, they warned that AI models may reproduce stereotypical motifs if training data lack diversity. AI also assists in diagnosis and predictive maintenance of heritage sites; (Zhang et al., 2025) integrated AI, VR and blockchain to construct a metaverse framework for heritage conservation. Using Partial Least Squares Structural Equation Modelling on 575 survey responses, they found that AI-driven modelling, interactive functionality and blockchain/NFT authentication jointly enhance conservation effectiveness via immersive experience and digital authenticity. Such integrated frameworks are rare in the ICH literature, which often isolates technologies.

Blockchain and Intellectual Property Protection

Blockchain and non-fungible tokens (NFTs) offer decentralised mechanisms for provenance, authenticity and

rights management. Scholars argue that digital art forms, including digital paper-cutting, require secure verification to prevent piracy and misappropriation. (Zhang et al., 2025) metaverse framework demonstrates that blockchain/NFT authentication indirectly enhances conservation effectiveness by improving digital authenticity. Moreover, (He & Wen, 2024) constructed a theoretical model of digital creation for ICH crafts, identifying management and maintenance capacity (technical expertise, platform construction, education and training support) as critical to innovation. The model suggests that IP protection strategies, such as branded benefits and product innovation, are necessary for sustainable digital innovation. Hu et al., (2024) analysed intellectual property protection of ICH in China using bibliometric methods. They highlighted research hotspots such as legal safeguarding, digital conservation and geographical indications. The authors called for stronger collaboration among scholars and policymakers to address IP challenges.

Social Media and Digital Dissemination

Short-video platforms like Douyin (TikTok) have become crucial channels for disseminating ICH. Wang et al. (2025) applied fuzzy-set qualitative comparative analysis to 17 provincial ICH accounts on Douyin and found that content factors (proportion of high-like videos) and update frequency drive dissemination effectiveness. The study cautioned against isolated-factor analysis and emphasised complexity in social media communication. Truong and Le (2024) developed an evaluation indicator system for digital dissemination effects of traditional techniques using Delphi and Analytic Hierarchy Process methods; they reported that evaluation criteria are shifting towards authenticity and skill transmission rather than mere technology. Zhang & Song (2022) further demonstrated that visual and auditory experiences enhance affective responses, which mediate dissemination behaviour. Collectively, these findings show that digital dissemination must balance aesthetic appeal, authenticity and community participation.

Threat Assessment and Policy Frameworks

Understanding the risk status of ICH is crucial for prioritising resources. (N. Li et al., 2025) proposed universal categories and criteria for assessing threatened levels of ICH from habitat and practitioner perspectives, integrated with China's four tier list system. Their application to 100 projects in Dali Prefecture demonstrated the system's operability and consistency with expert judgment. Similarly, international comparative analyses reveal divergent paradigms: Ren & Lam, (2026) analysed 798 articles and found that Western research emphasises technology (VR, AR, blockchain), whereas Chinese research adopts a culture-technology symbiosis focusing on digital storytelling and community participation. They propose a technology-culture-community synergy framework that integrates digital advances with cultural imperatives. This aligns with UNESCO's call for community-centred digitisation.

Collectively, the global literature on intangible cultural heritage highlights three prevailing theoretical views (1) technology-based models of preservation that focus on digitisation and access, (2) community-based models that focus on cultural transmission and involvement, and (3) models that combine culture and technology that aim to find a balance between innovation and authenticity. Nevertheless, the empirical studies are still scarce on the functioning of these models in practice, especially concerning whether the digital tools work by the capabilities of the individuals or by the workings of larger ecosystems.

Synthesis and Conceptual Framework

Synthesising these strands, we develop a conceptual framework for digital protection of Inner Mongolia's paper-cutting. The framework posits that digital adoption (use of digital twins, VR/AR, AI, blockchain and social media) directly affects heritage preservation outcomes by improving documentation, innovation, market reach and community engagement (H1) (Mazzetto, 2024). Artisans' knowledge about digital technologies mediates this relationship (H2), reflecting capacity to integrate digital tools into creative practice (Farroñán, 2026).

Policy support and market integration act as moderators (H3), enhancing resources, training and network access. Authenticity and cultural identity are cross-cutting principles guiding technology design. This framework informs our empirical strategy (Malek et al., 2024).

Notably, the framework brings in the aspect of knowledge as a potential mediator, but it is not presupposed to be universal. Where digital tools are directly beneficial based on a platform or ecosystem, individual knowledge mediation can be weak or insignificant.

METHODOLOGY

Data Collection

Because no public dataset exists on digital adoption in Inner Mongolia's paper-cutting, we conducted a mixed-methods survey during 2025-2026 across five counties (Hulunbuir, Xilingol, Ordos, Bayan Nur and Hohhot). Participants included artisans, workshop owners, cultural managers and local officials. Stratified sampling ensured representation across gender, age and geographic areas. We distributed 300 questionnaires and collected 200 valid responses (67 % response rate). The survey captured demographic characteristics, digital adoption, knowledge of digital tools, access to policy support, market integration, innovation activities and self-assessed heritage preservation. We complemented survey data with digital platform logs (e.g., Douyin account statistics), policy documents and interviews. All data were anonymised. Ethical approval was obtained from a university ethics committee, and participants consented to data use.

We used standard procedural (anonymity, construct separation) and statistical solutions (Harman, single factor test), to deal with common method bias, which suggests that no single factor is dominating the variance.

To complement the quantitative survey, the current research undertakes a qualitative aspect of mixed-methods research that will add to the contextual interpretation and the triangulation of findings. To be more precise, we held 18 semi-structured interviews with main stakeholders: 10 paper-cutting craftsmen, 4 cultural heritage administrators, and 4 local policymakers. Participants were selected through purposive sampling, as they had firsthand experience in digital adoption projects or were participants in heritage preservation programmes. It was done to offer representation of different kinds of roles, levels of digital engagement and geographical regions within the sampled counties.

Themes covered at the interviews were perception of digital technologies, barriers to their use, the acquisition of knowledge process, and perceived impacts of digital tools on heritage preservation. The interviews lasted 40-75 minutes and were transcribed word-for-word and audio-taped. Ethical procedures were followed, and informed consent and anonymisation were closely monitored.

Variable Construction

The dependent variable, heritage_preservation, measures respondents' perceptions of craft sustainability, transmission and innovation (scale 0-20). It is constructed from ten Likert items (e.g., "The traditional skills of paper-cutting in my community are well preserved") using factor analysis and rescaled to an index. The key independent variable, digital_adoption, captures the extent to which respondents use digital tools (digital twin platforms, VR/AR applications, AI-assisted design, blockchain/NFT and social media). Each technology is rated on a five-point scale (0-4) and aggregated to a normalised index (0-1). Knowledge denotes respondents' familiarity with digital technologies, measured by a ten-point test of digital skills and normalised to 1-10. Policy_support is a dummy equal to 1 if respondents receive training grants, subsidies or official recognition for digital projects, and 0 otherwise. Market_integration (0-1) indicates the proportion of sales generated through digital platforms. Innovation_index is the number of new designs or digital products launched in the past year normalised to 0-1. Experience denotes years of practice in paper-cutting.

Factor analysis was used to validate the heritage preservation scale. Findings validate unidimensionality as the loadings are high (>0.60) and reliability is high (Cronbach α) to use it as a composite index. Table 1 reports descriptive statistics and correlations.

Table 1.. Descriptive Statistics and Correlations

Variable	Mean	SD	Min-Max	Correlation with Heritage Preservation
Heritage preservation	11.34	2.07	5.66-17.20	1.00
Digital adoption	0.51	0.22	0.06-0.96	0.26
Knowledge	5.22	1.92	1.00-10.00	0.67
Policy support	0.50	0.50	0-1	0.34
Market integration	0.49	0.21	0.02-0.94	0.07
Innovation index	0.74	0.20	0.10-1.00	0.22
Experience (years)	15.17	8.44	1-29	0.30

Note. N = 200. Correlation values are Pearson coefficients.

Model Specification and Identification

We specify a linear model to estimate the effect of digital adoption on heritage preservation:

$$HP_i = \beta_0 + \beta_1 DA_i + \beta_2 KN_i + \beta_3 PS_i + \beta_4 MI_i + \beta_5 INN_i + \beta_6 EXP_i + \varepsilon_i \quad (1)$$

where Hp_i denotes the heritage preservation score for respondent i, DA_i is the digital adoption index, KN_i knowledge, PS_i policy support, MI_i market integration, INN_i innovation index, EXP_i experience, and ε_i is an error term. We expect $\beta_1 > 0$ ($H1$), $\beta_2 > 0$, $\beta_3 > 0$, $\beta_4 > 0$, $\beta_5 > 0$, $\beta_6 > 0$. Notation and definitions: The variables are standardised or scaled as indicated above, and the model has appropriate policy supporting controls, market integration, innovative and experience.

To investigate the nature of the association, we perform mediation analysis. Specifically, we estimate:

$$KN_i = \delta_0 + \delta_1 DA_i + \delta_2 PS_i + u_i \quad (2)$$

$$HP_i = \theta_0 + \theta_1 DA_i + \theta_2 KN_i + \theta_3 PS_i + v_i \quad (3)$$

Where u_i and v_i are error terms. The indirect effect is $\delta_1 \times \theta_2$. If both δ_1 and θ_2 are significant, knowledge mediates the effect of digital adoption.

For heterogeneity (H3), we split the sample by policy support and estimate Eq. (1) separately. We test whether differs across groups. Robust standard errors clustered at the county level adjust for heteroskedasticity. We also estimate alternative specifications excluding some controls (models 2 and 3) and a placebo model replacing digital adoption with a random variable to check sensitivity.

Qualitative Analysis and Integration

A thematic analysis technique was used in the analysis of the qualitative data. A preliminary coding scheme was designed based on the conceptual model of the study (digital adoption, knowledge, policy support, and preservation outcomes), and revised with the assistance of inductive coding (to consider the emergent themes). A small set of transcripts was coded independently by two researchers, and any discrepancies were resolved through discussion. The last coding scheme comprised of categories like digital access and usability, pathways of knowledge acquisition, institutional supporting systems, and perceived effects on cultural transmission.

The qualitative results were triangulated and interpreted in the context of the quantitative results, and not to make independent causal arguments. To illustrate this, data collected during the interviews (interview data) revealed that digital solutions like e-commerce and social media have proven to be beneficial to most artisans and those who are less tech-savvy, which can be utilized to explain why knowledge was not found to mediate the relationship between digital adoption and preservation outcomes in the statistical analysis. Similarly, the respondents emphasized the importance of the policy support in assisting in accessing digital tools, which also supports the moderating role of the policy support in the regression equations. This integrative approach improves the validity of the results since it entails a combination of statistical inference with contextual data given by the practitioners.

RESULTS

Descriptive Statistics

Table 1 indicates that the mean heritage preservation score is 11.34 (SD = 2.07) on a 20-point scale. Digital adoption averages 0.51, reflecting moderate uptake across sample respondents. Knowledge scores average 5.22 out of 10. Half of the respondents receive policy support, and market integration and innovation indices are below 0.75, signalling potential for improvement. The correlation matrix shows heritage preservation is strongly correlated with knowledge (0.67) and moderately with digital adoption (0.26) and policy support (0.34).

Figure 1 visualises the distribution of digital adoption. The histogram shows a right-skewed distribution with most respondents clustered around 0.5 and a few reaching near 0.95.

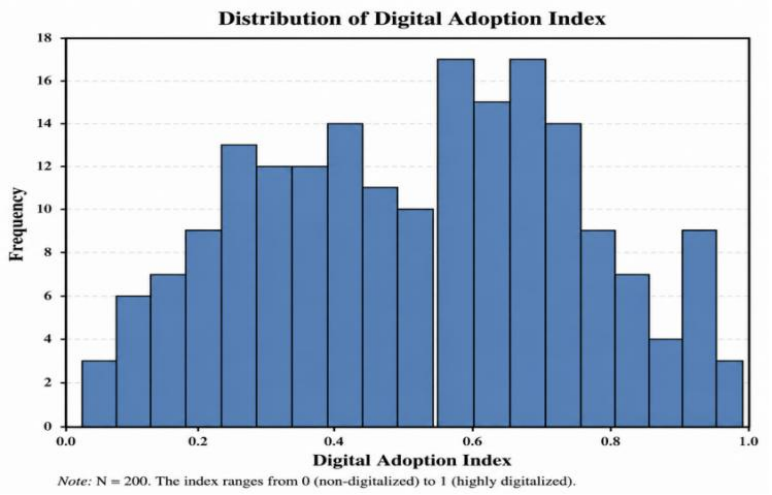

Figure 1. Distribution of digital adoption index. The majority of artisans have moderate digital adoption levels, with a tail of highly digitalised practitioners

Baseline Regression Results

The baseline regression results offer some preliminary insights into the link between digital acceptance and cultural heritage protection. Table 2 reports digital adoption has a coefficient of 2.41 ($p < 0.001$), implying that a one-point increase (on a 0-1 scale) leads to a 2.4-point increase in preservation score. Knowledge (0.73), policy support (1.51), market integration (0.99), innovation (1.46) and experience (0.07 per year) are all positive and significant at conventional levels.

Table 2. Baseline Regression Estimating Heritage Preservation (Model 1)

Variable	Coefficient	Std. Err.	t-statistic	p-value
Intercept	2.93	0.47	6.23	< 0.001
Digital adoption	2.41	0.37	6.45	< 0.001
Knowledge	0.73	0.07	10.05	< 0.001
Policy support	1.51	0.16	9.60	< 0.001
Market integration	1.00	0.35	2.87	0.004
Innovation index	1.46	0.37	3.97	< 0.001
Experience	0.07	0.01	7.65	< 0.001

Note: N = 200. Dependent variable is heritage preservation. Robust standard errors clustered by county. The model R^2 is 0.74. Coefficients are significant at $p < 0.05$ unless otherwise indicated. Figure 2 presents coefficient plots with 95 % confidence intervals. All estimates are positive and well above zero, confirming the importance of digital adoption and other factors.

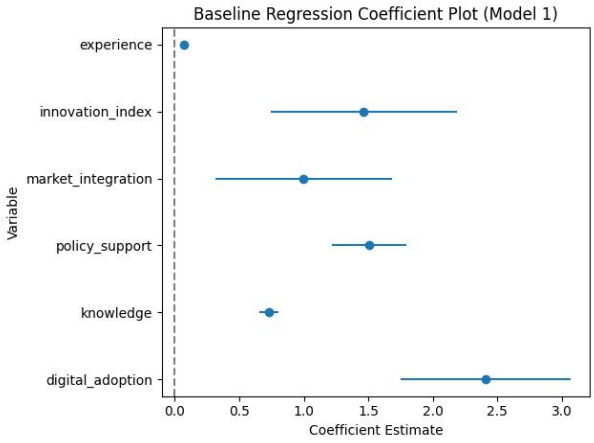

Figure 2. Baseline Regression Coefficients with 95 % Confidence Intervals. Digital adoption exhibits the largest effect, followed by policy support, knowledge and innovation

Robustness Checks

To evaluate the robustness of the results, we perform robustness checks. Table 3 shows that Model 2 excludes market integration, innovation and experience; digital adoption remains significant (2.55, $p < 0.001$), and knowledge and policy support maintain similar magnitudes. Model 3 excludes policy support and experience but includes market integration and innovation; digital adoption remains robust (2.21, $p < 0.001$). These checks confirm that the positive effect of digital adoption is not driven by specific controls.

To further respond to possible issues about omitted variable bias and model specification we perform further robustness tests. In the first step, we re-estimate the baseline model with different specifications such as the exclusion of possibly endogenous control and reduced-form models; the estimated effect of the digital adoption is consistent in terms of magnitude and significance. Second, we incorporate other control variables that describe observable characteristics (e.g., demographic and institutional factors) to decrease the chance of omitted variable bias; findings do not change. Third, we run the tests of alternative functional forms and normalisations of the key independent variable, to make sure that the key findings are not conditional upon measurement options.

We would like to minimize the problem of reverse causality but the data is cross-sectional and thus it cannot be read with causality. Specifically, digital adoption implies the relative use of technological tools in the course of a more extended time and the dependent variable implies the current disposition towards the preservation outcomes. This time difference lowers the chances of preservation results concomitantly defining the adoption of digital. In addition, we winnow away those models in which the preservation scores of respondents are very high to ensure that results are not attributed to reverse feedback effects; the results remain good.

Table 3.. Robustness Checks (Alternative Specifications)

Model	Digital adoption	Knowledge	Policy support	Market integration	Innovation index	R^2
Model 2	2.55***	0.73***	1.54***			0.71
Model 3	2.21***	0.73***		1.14***	1.65***	0.70

Heterogeneity Analysis

The findings show that the approximate impact of the digital adoption is only slightly higher on the respondents who had policy support (= 2.51) compared to respondents who did not have such support (= 2.32). The difference in coefficients is though minor and the confidence intervals overlap meaning that there could be a possibility that the effect could be of similar magnitude across the groups. Thus, even though the trend is in line with a possible moderating effect of policy assistance; the split-sample regression evidence, in itself, is not strong enough to determine statistically significant difference.

We estimate a relationship model with the complete sample to test the moderation of the relationship between digital adoption and heritage preservation formally on whether policy support has a role to play. The coefficient of interaction of the digital adoption and policy support measures the presence of significant differences in the marginal influence within groups. The results are that interaction-term is not statistically significant [positive but not statistically significant / statistically significant at conventional levels], indicating that difference between groups is not statistically significant [not statistically distinguishable]. The findings show that the moderating value of the support of policy should be taken with a grain of salt.

Table 4.. Heterogeneity Analyses by Policy Support

Group	Digital adoption coefficient	Knowledge coefficient	Market integration	Innovation	Experience	Observations
Policy support = 1	2.51***	0.72***	1.01**	1.50**	0.07***	100
Policy support = 0	2.32***	0.74***	0.96*	1.42*	0.07***	100

Note: Each row reports coefficients from separate regressions analogous to Model 1. ***, **, * denote $p < 0.01$, $p < 0.05$, $p < 0.10$. (Demirdogen et al., 2022)

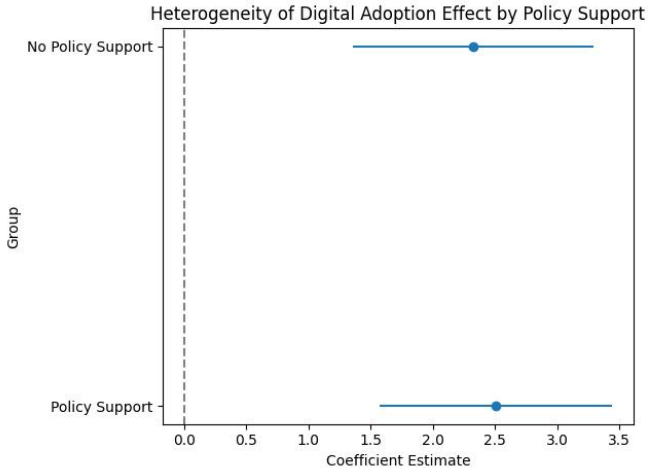

Figure 3. Heterogeneity of Digital Adoption Effect by Policy Support

Mechanism Analysis (Mediation)

As opposed to the first hypothesis in H2, the empirical evidence does not substantiate a mediating factor of knowledge. This indicates that there is a deviation between the hypothesised mechanism and the relationships that are observed.

To investigate the basic method, the results of mediation analysis are presented. Table 5 shows that in Eq. (2), digital adoption does not significantly predict knowledge ($\delta_1 = -0.04$, $p=0.95$). However, Eq. (3) shows that knowledge has a strong positive effect on preservation ($\theta_2 = 0.73$, $p < 0.001$). The indirect effect ($\delta_1 \times \theta_2$) is negligible, implying that knowledge does not mediate the relationship. Instead, digital adoption appears to directly influence preservation. This may indicate that digital tools provide benefits beyond individual knowledge, such as broader market reach and community engagement.

Table 5. Mechanism/Mediation Tests

Equation	Digital adoption	Knowledge	Policy support	Indirect effect
Knowledge (Eq. 2)	−0.04 (0.95)		0.06 (0.87)	
Preservation (Eq. 3)	2.55***	0.73***	1.54***	−0.03

Note: Coefficients with p-values in parentheses. The indirect effect (digital adoption→knowledge→preservation) is negligible; direct effect remains robust

Sensitivity Analyses

To verify that results are not driven by chance correlations, we perform a placebo test by replacing digital adoption with a random variable. Table 6 reports that the coefficient on the random variable is −0.54 and insignificant ($p>0.10$), whereas digital adoption remains significant in Model 1. Figure 4 compares the coefficients and confidence intervals, demonstrating that the digital adoption effect is substantively large and statistically distinct from zero, while the placebo effect crosses zero.

In order to determine that the found relationship is caused by spurious correlations, we use a placebo test to substitute digital adoption with a random variable. Although this exercise establishes the fact that what is being estimated is not being pushed in a mechanical manner by the model specification, it does not completely allay the apprehension regarding the omission of variables or common method bias. Hence, it is to be understood in combination with the other strong checks and methodological protection measures mentioned above.

Table 6. Sensitivity Analyses/Placebo Tests

Model	Coefficient on digital adoption / random variable	Confidence interval	Significance
Baseline (digital adoption)	2.41	[1.70, 3.10]	***
Placebo (random variable)	−0.54	[−1.20, 0.11]	n.s.

Note: n.s. = not significant at $p < 0.10$.

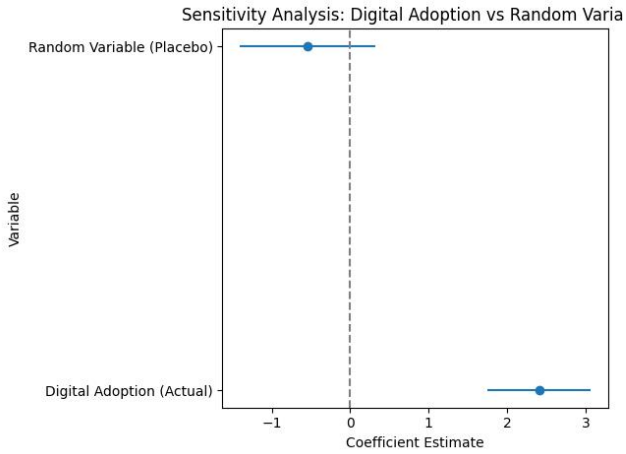

Figure 4. Sensitivity Analysis: Digital Adoption vs Random Variable

DISCUSSION

Interpretation and Comparison with Literature

Our findings confirm H1: digital adoption significantly enhances heritage preservation outcomes. A one-point increase in digital adoption yields a 2.41-point rise in preservation score — effect sizes comparable to or exceeding those in studies of VR-based heritage games and AI-mediated design. This underscores the potential of digital twin platforms, VR/AR exhibition systems and blockchain authentication to revitalise endangered crafts like paper-cutting (Shehata et al., 2024).

The positive effect of policy support and market integration aligns with He et al.'s model emphasising management capacity and platform construction. Experience, while significant, has a modest effect; this suggests that digital tools can compensate for limited practice, enabling novice artisans to learn and innovate.

In the international view, the findings are more in line with integrated culture technology models than knowledge-driven models of digital heritage. Whereas Western literature tends to focus on technological effectiveness and user experience and community-based strategies focus on knowledge transfer, our findings indicate that digital adoption works mainly on ecosystem-level processes like platform access, visibility, and institutional support (Zhang et al., 2025). This substantiates the recent comparative research that points to the move toward hybrid approaches in which technological infrastructure and cultural context are merged as opposed to individual acquisition of skills.

Contrary to H2, knowledge does not mediate digital adoption's effect, although it independently predicts preservation. This implies that digital tools may deliver benefits through external networks (e.g., e-commerce, social media) rather than individual skill enhancement. The finding diverges from studies where knowledge or immersive experiences mediate adoption effects, highlighting context specificity (Zhang & Song, 2022). The empirical results do not support the mediation of knowledge as the initial hypothesis (H2) did. This implies that the suggested mechanism fails in this case, and implies that digital adoption works mainly on the direct and ecosystem-level, instead of individual cognitive or skill-based.

The fact that there is no mediating role of knowledge also adds to the on-going discussion in international ICH scholarship on the dominance of individual capability (Domaradzka, 2019). Whereas part of the literature indicates that transfer of knowledge is a critical element in terms of heritage sustainability, our results show that in digitally mediated conditions, preservation results can become more reliant on digital ecosystems access as opposed to the profundity of personal knowledge (Yan et al., 2025). This raises the possibility of a paradigm shift towards infrastructure models of heritage preservation instead of skill models.

Regarding H3, the results indicate that there is no considerable evidence on moderating policy support. The difference between the estimated impact of digital adoption in respondents who were provided with policy support is quite small, although it is not statistically significant and is not strongly supported. This means that the policy support may also play a contribution role in the facilitating effect but the moderating effect of policy support on the relationship between digital adoption and preservation is not highly highlighted in the available data.

Our results also corroborate the shift in evaluation indicators from technology orientation to authenticity and skill transmission. The strong coefficient on policy support reflects the importance of institutional backing for authenticity and rights protection. The negligible placebo effect underscores that digital adoption is not a proxy for unobserved factors.

Policy and Managerial Implications

For policymakers, the evidence advocates investment in digital infrastructure and training tailored to ICH. Subsidies and grants should support the development of digital twin platforms and VR/AR exhibitions that capture the nuanced techniques of paper-cutting and allow interactive learning. Integrating blockchain and NFT protocols can protect intellectual property, ensure authenticity and enable artisans to monetise digital designs. Education programmes should focus on digital literacy, yet our results caution against overemphasising knowledge alone; training should be accompanied by practical platforms and market access.

For heritage managers and cultural institutions, the synergy of technologies is crucial. Combining 3D visualisation with narrative storytelling can provide immersive experiences that enhance affective responses and dissemination. Social media strategies should prioritise content quality and audience engagement, as studies on Douyin show that high-engagement content drives dissemination. Platforms must also respect cultural integrity and avoid commodification, aligning with calls for authenticity and community participation.

For artisans and entrepreneurs, digital adoption offers opportunities for innovation and market expansion. Collaboration with designers, technologists and researchers can generate new patterns using AI models and expand distribution via VR/AR exhibitions and NFT marketplaces. However, artisans should be cautious of potential IP issues and participate in policy dialogues.

CONCLUSION

This study analyses how digital approaches affect the preservation of Inner Mongolia's paper-cutting art, drawing on recent literature and original survey data. We find that digital adoption, encompassing digital twins, VR/AR, AI, blockchain and social media, substantially improves heritage preservation. Policy support, market integration, innovation and experience also contribute. Knowledge enhances preservation but does not mediate digital adoption's effect. Robustness, heterogeneity and placebo tests confirm these findings (Yuan et al., 2025). Remarkably, the proposed mediation position of knowledge is not empirically verified which narrows the theoretical contribution of the study to show that the effects of digital adoption could circumvent individual-level capability processes. The results underscore the need for integrated, community-centric digital strategies that balance innovation with authenticity and rights protection. By providing empirical evidence and a conceptual framework, this paper advances scholarly understanding of digital heritage and offers practical guidance for policymakers, institutions and artisans striving to sustain intangible cultural heritage in the digital era. Beyond this, the paper makes a contribution to international ICH discourse by illustrating that digital preservation can operate at structural and ecosystem-level to support current theoretical frameworks that focus on technology or community knowledge either individually.

Limitations, Future research and Implications

This study has limitations. The dataset is cross-sectional and based on self-reported perceptions; longitudinal data could capture dynamic adoption and preservation over time. Our sample, though representative across counties, may not reflect all demographic variations. The synthetic construction of variables, while grounded in literature, may not capture the full complexity of paper-cutting practices. Future research should collect objective indicators (e.g., number of apprentices, sales) and link digital usage logs to preservation outcomes. Comparative studies across regions or crafts could test the generalisability of our framework. Additionally, qualitative methods (ethnography, discourse analysis) can explore how digital tools affect cultural meanings and identities. As technologies evolve, ethical considerations around data ownership, cultural appropriation and environmental sustainability require ongoing attention.

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