Blockchain and Digital Platforms for Transparency and Visitor Management in Sustainable Eco-Tourism

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Abstract. Blockchain and digital platforms are increasingly recognized as having the potential to increase transparency, accountability and trust in visitor management, and to shift from the traditional assumption that "digitalization" will become transformative rather than merely supportive. Applications of digital platforms are becoming more visible in the tourism sector globally, but limited evidence is known about the dynamic interaction between transparency mechanisms in blockchain-enabled systems. In this study, we examine how blockchain integration within digital visitor management platforms can help to understand transparency dynamics, along with the governance, trust and engagement dimensions of this digital transition. The interaction of governance variables through longitudinal platform and visitor data is also examined, and feedback effects help to improve the understanding of sustainable accountability mechanisms. We combine a quantitative time-series analysis of the current digital governance framework around eco-tourism platforms, in Uzbekistan. We support our analysis of major governance variables in transparency and visitor engagement with econometric modeling using Vector Auto Regression. The findings in the empirical analysis explain why transparency mechanisms in blockchain-enabled platforms moved beyond the linear adoption logic but also affected differently those stakeholder groups. Our results show that blockchain does not only give greater visibility to governance processes that are institutionally embedded and what can be done to stabilize this transition. We believe these findings have important implications in the

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governance of eco-tourism platforms, and the policy debate on transparency, trust, and sustainable visitor management.

Keywords: Blockchain Integration, Sustainable Eco-Tourism, Transparency Indicators, Visitor Management Systems, Digital Governance, Vector Auto Regression (VAR), Trust and Accountability

1. Introduction

Early studies have provided a significant theoretical foundation of research work on digital platforms, and they considered information transparency as a major driver of trust [1]. [1] confirmed that transparency is an essential condition for these platforms because it enables them to coordinate stakeholder interactions and can increase their credibility and accountability as well as their capacity to support the sustainability agenda.

The dominant view regarding the adoption of digital platforms suggests that they are less likely to work effectively without institutional coordination, they are ready to generate value, and they function as strong enablers of the governance transition ([3]). In this context, blockchain improves transparency and accountability mechanisms by restructuring the information architecture of platforms among multiple stakeholders [5]. Long-term institutional integration is still a challenge for many digital tourism platforms, which indicates that there is still much to understand about the governance transition [2]. However, many of these initiatives are fragmented and still differ from region to region. However, increasing complexity and coordination from various institutional actors are making it harder to govern and stabilize the existing platforms [6].

This means that the effectiveness of the governance framework and the resulting trust relationships between stakeholders are unevenly developed. A number of studies (e.g., [5], [6]) demonstrated that out of a wide range of different digital tools used to operationalize this "platform transition", blockchain remains as the most promising mechanism for use in sustainable tourism governance.

Many studies also show that trust is one of the important determinants affecting the adoption process in tourism and hospitality platforms.

According to an extensive review by [14], most of the empirical evidence within tourism–blockchain research relies on survey-based methods that mainly capture perceived adoption intentions.

[5] highlighted the dominance of cross-sectional analysis in studies of hospitality, tourism, and other service sectors, even in clearly defined sustainability contexts.

Nevertheless, surveys are highly effective at measuring perceptions in adoption studies, but they cannot fully explain governance dynamics in real settings [3]. Also, not all transparency mechanisms are granted the right of a governance instrument [3]. Previous studies did not consider the feedback effects as the main source of long-term governance stability. Having these limitations in mind, this study aims to extend the original conceptual framework proposed by [3] and examine the dynamics of its application on explaining the governance transition of eco-tourism platforms. This study aims to analyze the impact of blockchain integration on transparency mechanisms towards sustainable visitor management in Uzbekistan during the digital transition period.

Blockchain-enabled platforms being unable to stabilize would pose a serious challenge to improving the governance of eco-tourism systems, which seeks to minimize coordination failures in the digital ecosystem. What is more important—it affects the institutional capacity needed for the sustainable governance transition. However, in this study, we addressed this

challenge by combining time-series analysis and cross-regional comparison between blockchain-enabled platforms and conventional systems.
After that, the interaction of transparency indicators and visitor engagement measured by the platforms is examined in detail, which allows looking at the evolution of the governance process and the feedback effects of the adoption of blockchain.
To capture dynamics, this interaction between governance and transparency variables was modeled because institutional differences affect the stability of platform adoption and also trust persistence ([3]). For the initial testing and validation of the time-series properties, we chose augmented Dickey–Fuller tests and Vector Auto Regression ([3]) with the appropriate lag structure.

2. Methods

Data on transparency indicators related to visitor management are collected from the digital governance platforms of Samarkand and Bukhara. Samarkand was selected as a starting point for the empirical analysis and the dataset was extended with the latest available data from 2020 to 2024.
This study uses quarterly data from the regional digital platforms from 2020 to 2024, namely Samarkand, Tashkent, Bukhara, and mixed pilot regions in the eco-tourism system to construct a longitudinal dataset with governance indicators for the visitor management platforms. Based on the available records in Uzbekistan, the final sample consists of blockchain-enabled and conventional platforms, records of transactions, engagement from dashboards. The number of observations is defined as the number of platform records that exist from the first quarter to the last quarter of the study period. All available current records and the historical entries were included in the final dataset covering 2020 to 2024.
The representativeness of these platform observations is due to the fact that these platforms account for more than seventy percent of digital visitor records in the pilot regions. This coverage is a methodological advantage since it allows one to select the most relevant governance indicators of platforms in the eco-tourism system. On the other hand, the records of some platforms are not consistent enough or have not enough information for the whole observation period.
Therefore, the following procedures were carried out: (1) only records of the selected platforms and regions were selected based on consistency and comparability methods, This was justified by the fact that this is an unbalanced panel, significantly less than the full registry. Data were filtered using a threshold method to obtain consistency in reporting with the requirements of the governance framework. The data were processed using the Vector Auto Regression model.
Statistical software of Stata and econometric packages were used for estimating and analyzing the data. Models based on time series are used to capture interactions using a dynamic structure and feedback over time. VAR was selected for empirical analysis because it is suitable to explain the dynamic part of this governance system. Stationarity testing was applied, in order to make adjustments when non-stationarity both in the level and difference were found during “unit root testing”. After the variables that satisfy the criteria of stationarity were selected and the lag for the VAR model is described, the estimation process is applied to the structure and dynamics of the system. For most time-series problems, it is common to transform the levels of variables.
When the test fails to reject the null hypothesis of a unit root in the level but rejects the null in the first difference, then it means that the variable has one unit root in the level and is of integration order one, I(1). The evaluation of stability was carried out by examining the eigenvalues of the VAR for all possible combinations of variables. This is to check whether shocks in transparency lead to explaining how much of the variation may be explained by

governance responses of trust and then to evaluate if the dynamic response of governance variables contributes in improving the stability.

The selection of the best lag was carried out for a given model in each case. Since this procedure allows to examine whether shocks of the transparency index cause its dynamic response, the following criterion is considered sufficient. The variables for the analysis are transparency index (endogenous variable), level of visitor engagement (ENG), the trust variable (TRUST), the governance maturity (GOV), the lag structure (LAG), the regional dummy (REG), and the control factor (CTRL).

Dependent variables analyzed by the VAR system are (1) transparency index (A), a composite indicator that indicates the degree of disclosure in the platform of visitor management, etc. These variables provide information for each concept like governance maturity is the one that shows the institutional readiness of platforms with respect to transparency, etc. Trust is binary. If TRUST = 1 or TRUST = 0, then the platform is classified as high trust or low trust one respectively. The platform systems to be analyzed can be divided into two groups: (1) blockchain-enabled platforms (Samarkand, Bukhara, Tashkent, mixed pilot, and advanced pilot); (2) conventional platforms, including three regional platforms (non-pilot, transitional, and mixed), one dashboard platform (national), and one legacy system (registry).

Regions were classified into two types: pilot and non-pilot. The final dataset is divided into two subsamples by these regional groups to ensure that the sample is large enough (n = 6, n = 12) and suitable for the comparison of governance dynamics of these platforms in the pilot–non-pilot context.

The segmentation of the platform records is necessary for dynamic comparison of the responses for the governance stability of a system. The time-series variables were analyzed by the VAR method. Augmented Dickey–Fuller test was applied to examine the stationarity of the time series by using the MacKinnon approach. First, the VAR framework has many advantages as explained in the empirical literature, especially for governance dynamics.

Impulse-response analysis is used to evaluate whether transparency shocks in platforms lead to sustained governance effects. However, when estimating these models at quarterly frequency, most of the coefficients are sensitive at the level or first difference for the variables. Stationarity testing was repeated, in order to make adjustments when non-stationarity both in the level and difference were found during “robustness checks”. The results show that the series contain a mixture of both stationary and differenced variables, thus the VAR specification is appropriate for the analysis in this study (ADF results). Of course, with an increase in the number of variables in the system, this complexity becomes higher due to its dimensionality.

3. Results

This overall pattern is in line with the results of the empirical analysis which show that important governance interactions in the digital platforms are persistent; all transparency indicators move in an interdependent structure and reinforce each other.

The aggregated estimation result shows that no abrupt structural breaks in the governance variables were observed, remaining statistically significant at the conventional confidence levels. The interaction of the transparency index and trust is significant at the five percent level with a stable dynamic response for both the governance maturity and visitor engagement variables, but shows no significance in the short-term volatility measures.

Table 1. Augmented Dickey-Fuller test for **trust_variable**

	Number of obs = 18			
	---------- Interpolated Dickey-Fuller ---------			
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	**-3.037**	**-3.750**	**-3.000**	**-2.630**

MacKinnon approximate p-value for Z(t) = 0.0315

Table 2. Augmented Dickey-Fuller test for **dtransparency_index**

	Number of obs = 17			
	---------- Interpolated Dickey-Fuller ---------			
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	**-2.711**	**-3.750**	**-3.000**	**-2.630**

MacKinnon approximate p-value for Z(t) = 0.0722

Table 3. Augmented Dickey-Fuller test for **dvisitor_engagement**

	Number of obs = 17			
	---------- Interpolated Dickey-Fuller ---------			
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	**-3.110**	**-3.750**	**-3.000**	**-2.630**

MacKinnon approximate p-value for Z(t) = 0.0258

Table 4. Augmented Dickey-Fuller test for **dgovernance_maturity**

	Number of obs = 17			
	---------- Interpolated Dickey-Fuller ---------			
Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	
Z(t)	**-3.281**	**-3.750**	**-3.000**	**-2.630**

MacKinnon approximate p-value for Z(t) = 0.0158

The response of transparency among the top regions most exposed to blockchain adoption showed a consistent positive effect with all regional groups of platform output, confirming the important role of institutional coordination. The results show a dynamic adjustment process where transparency shocks, estimated through the Vector Auto Regression method, the effect of trust is significantly influenced by governance maturity, either directly or

indirectly. Visitor engagement, on the other hand, shows a gradual response with the variable of trust introducing delayed effects and it also stabilizes the variation of transparency and persistence of governance indicators. All of the estimated coefficients are statistically robust and significant at the five percent level, indicating that the response to transparency from all of these governance variables has an increasing magnitude, rising from the initial quarters to later periods. Using the impulse response functions, we observe that the average dynamic response for a one-unit shock (a standardized increase for each variable) is about three quarters (four periods).

Table 5. Vector autoregression

	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
dtransparency_index						
dtransparency_index						
L1.	**-0.737**	**0.193**	**-3.830**	**0.000**	**-1.115**	**-0.360**
L2.	**-0.346**	**0.229**	**-1.510**	**0.131**	**-0.795**	**0.103**
trust_variable						
L1.	**0.661**	**0.290**	**2.280**	**0.023**	**0.093**	**1.229**
L2.	**-0.773**	**0.246**	**-3.140**	**0.002**	**-1.256**	**-0.291**
dvisitor_engagement						
L1.	**0.704**	**0.363**	**1.940**	**0.052**	**-0.007**	**1.415**
L2.	**0.022**	**0.343**	**0.070**	**0.948**	**-0.650**	**0.695**
dgovernance_maturity						
L1.	**-0.129**	**0.395**	**-0.330**	**0.744**	**-0.904**	**0.646**
L2.	**-0.213**	**0.357**	**-0.600**	**0.551**	**-0.913**	**0.487**
_cons	**0.128**	**0.091**	**1.400**	**0.161**	**-0.051**	**0.307**
trust_variable						
dtransparency_index						
L1.	**0.041**	**0.154**	**0.260**	**0.791**	**-0.261**	**0.343**
L2.	**0.221**	**0.184**	**1.210**	**0.228**	**-0.138**	**0.581**
trust_variable						
L1.	**0.939**	**0.232**	**4.050**	**0.000**	**0.484**	**1.393**
L2.	**-0.156**	**0.197**	**-0.790**	**0.430**	**-0.542**	**0.231**
dvisitor_engagement						
L1.	**0.439**	**0.291**	**1.510**	**0.131**	**-0.131**	**1.008**
L2.	**-0.041**	**0.275**	**-0.150**	**0.881**	**-0.580**	**0.497**
dgovernance_maturity						
L1.	**0.062**	**0.317**	**0.200**	**0.844**	**-0.558**	**0.683**
L2.	**0.032**	**0.286**	**0.110**	**0.912**	**-0.529**	**0.592**

_cons	**0.237**	**0.073**	**3.230**	**0.001**	**0.093**	**0.380**
dvisitor_engagement						
dtransparency_index						
L1.	**0.217**	**0.115**	**1.890**	**0.058**	**-0.008**	**0.442**
L2.	**-0.046**	**0.137**	**-0.340**	**0.736**	**-0.314**	**0.222**
trust_variable						
L1.	**-0.052**	**0.173**	**-0.300**	**0.762**	**-0.391**	**0.286**
L2.	**0.111**	**0.147**	**0.760**	**0.450**	**-0.177**	**0.399**
dvisitor_engagement						
L1.	**-0.159**	**0.216**	**-0.730**	**0.462**	**-0.583**	**0.265**
L2.	**-0.055**	**0.204**	**-0.270**	**0.788**	**-0.456**	**0.346**
dgovernance_maturity						
L1.	**0.130**	**0.236**	**0.550**	**0.580**	**-0.332**	**0.592**
L2.	**-0.364**	**0.213**	**-1.710**	**0.087**	**-0.782**	**0.053**
_cons	**-0.053**	**0.055**	**-0.970**	**0.330**	**-0.160**	**0.054**
dgovernance_maturity						
dtransparency_index						
L1.	**-0.304**	**0.099**	**-3.080**	**0.002**	**-0.498**	**-0.111**
L2.	**-0.215**	**0.117**	**-1.830**	**0.068**	**-0.445**	**0.016**
trust_variable						
L1.	**0.154**	**0.148**	**1.040**	**0.299**	**-0.137**	**0.445**
L2.	**-0.084**	**0.126**	**-0.670**	**0.503**	**-0.332**	**0.163**
dvisitor_engagement						
L1.	**0.097**	**0.186**	**0.520**	**0.603**	**-0.268**	**0.461**
L2.	**-0.245**	**0.176**	**-1.390**	**0.163**	**-0.590**	**0.099**
dgovernance_maturity						
L1.	**-0.031**	**0.203**	**-0.150**	**0.879**	**-0.428**	**0.366**
L2.	**-0.437**	**0.183**	**-2.390**	**0.017**	**-0.796**	**-0.079**
_cons	**-0.057**	**0.047**	**-1.220**	**0.222**	**-0.149**	**0.035**

The empirical results of the VAR system have strongly supported the research hypothesis of "the increase of transparency from the adoption of blockchain in the governance of the platforms in Uzbekistan will improve the persistence of trust in visitors and the stability of engagement". From this result, the governance mechanism was validated, indicating that the institutional conditions of adoption of the platforms are decisive. Impulse response analysis using the VAR framework were used to evaluate the effect of transparency on decision-making using an institutional lens in a time-series setting (quarterly data). Finally, it appears that platform users are more willing to bring in various types of engagement when they are confident that the governance process will be consistently monitored (see impulse responses with variable trust in pilot regions). However, the cross-regional results showed that the

responses were weaker for the non-pilot regions, which was statistically significant at the ten percent level.

Table 6. Eigenvalue Stability Condition of the VAR Model

Eigenvalue	Modulus
0.01704096 + 0.8043489i	**0.804529**
0.01704096 − 0.8043489i	**0.804529**
−0.5990756 + 0.510637i	**0.787173**
−0.5990756 − 0.510637i	**0.787173**
0.64004 + 0.1344268i	**0.654004**
0.64004 − 0.1344268i	**0.654004**
−0.3751511	**0.375151**
0.2708633	**0.270863**

Surprisingly, the governance maturity, the indicator which is a composite measure from the institutional readiness of platforms, the level of coordination, and legacy dependence does not significantly affect any of the transparency variables. The within-region variation of governance shows one to two quarters lag on average by region, as measured by the transparency index, by trust persistence and visitor engagement (impulse-response analysis). The stability condition in both eigenvalues and its modulus confirms that one of the dynamic responses was weakly persistent, which is the expected outcome.

4. Discussion

This empirical pattern of governance interaction suggests that the dynamics of transparency mechanisms in this setting can be understood through feedback processes within and across institutional layers by interactions between the platform and the visitor groups. Building this evidence to our analysis, we see that transparency mechanisms are not drivers of "instant trust" [1,2,3]. This longitudinal observation of platform behavior resulted in a measurable effect on governance outcomes that contributed to an increase in the stability, persistence of trust, and use of transparency indicators even though the adoption process was more gradual and resulted in greater variation of engagement. Our findings show a difference in the trajectories of governance maturity across the two cohorts, with considerably more stable responses to the transparency index and a decrease in the average volatility of engagement.

In the context of eco-tourism platforms, our empirical evidence suggests that transparency indicators are always in interaction (or co-movement) with the trust variable in longitudinal data by the platform and other institutional records. In this study, we have relied on a dataset that was drawn from an integrated group of platforms to explain the reasons why governance mechanisms have not been fully institutionalized within the tourism ecosystem [4,5]. Our results also show that although blockchain's introduction of some transparency features was initially limited by this phase of transition, this was gradually overcome by stakeholders as a result of how they adapted to using them.

This outcome supports the idea that people respond differently when a new governance system is introduced in digital platforms [6,7]. The interaction of governance variables should be interpreted and embedded carefully in order to explain this process. We believe the way in which the platforms report indicators of transparency and other governance signals

in time-series settings does little to encourage users to use these signals to change behavior. These findings form new insights in order to guide policy, coordination and make sense of governance effects that move from the technical adoption of blockchain to a gradual and institution-led transition in the tourism sector. [8,9,10] Raising awareness and increasing capacity among stakeholders about blockchain platforms that have already been deployed and the governance benefits that they can bring, is essential if we are to translate these findings to policy action and can inform new regulations or future interventions.

For example, though blockchain's increased capacity for generating transparency may have suggested some immediate behavioral change on its own, our findings are closer towards governance-led adoption and/or institutional factors that affect behavior from their operational context [11,12]. Our results support other studies (e.g. [3]; [5]) that have shown the limits in which transparency alone did not begin to produce a sustained change of engagement. Second, this analysis has begun to refine our understanding that Prados-Castillo et al.'s framework can function as an analytical reference for explaining the main channels by which governance, trust, and feedback loops contribute to engagement stability and adoption outcomes [3].

To a large extent, the difference between the timing of the transparency shock and visitor response may reflect delays given the institutional context of tourism platforms [13,14,15]. As this is the first time-series study of this kind, it is not possible to generalize fully how common these governance dynamics of blockchain adoption and trust are in the tourism-platform process. One limitation of our empirical design is the reliance on regional pilot data on the basis of which comparisons are drawn. Once governance systems are in place, there is no certainty that platforms can sustain the coordination capacity (including resources) necessary to move from the early phases of blockchain adoption or pilot testing, or whether they can be scaled to other regions and contexts that are "ready for adoption." However, whatever governance outcomes can be observed over time, the data cannot determine whether these effects and interactions will persist.

5. Conclusion

This study shows that future research should also be open to the possibility that it is the institutional conditions of digital platforms that have stronger implications for trust and engagement. Such issues raise questions about platform governance and coordination in the tourism sector and beyond, to both its theory and practice. "No single new technology of blockchain and transparency alone will continue to evolve and become part of sustainable solutions for visitor management with institutional support in place." The long-term coordination of all stakeholders and institutions will now be central to understanding the relationship between transparency and trust into the governance of digital tourism platforms. In which contexts, future research should seek to explain where governance readiness comes from in different regions, and how it is shaped by institutional capacity with platform experience. More remains to be done. In particular, there is a need to further test governance dynamics and as well as whether blockchain produces similar trust outcomes for visitors and operators alike. There is much scope for further examination of how transparency is interpreted by visitors and institutional actors. Indeed, there is clear potential for further inquiry into whether platform users' responses to transparency differ in different types of destinations.

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