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Can e-government online services offer enhanced governance support? A national-level analysis based on fsQCA and NCA

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ABSTRACT

Government online services are often considered a core component of e-government, generating significant interest not only among practitioners and scholars but also among policymakers because of their crucial role in enhancing a country's governance capacity. This study, which is based on the United Nations E-Government Survey's Online Service Index, the World Bank's Worldwide Governance Indicators, and the Global Innovation Index, investigates how e-government online services' technology, institutional frameworks, content provision, e-participation, and service provision, as well as innovation, enhance the national governance capacity and offer governance support. The research uses principal component analysis (PCA) for data preprocessing and combines necessary condition analysis (NCA) with fuzzy set qualitative comparative analysis (fsQCA) to provide empirical evidence. The study confirms the critical role of the aforementioned factors in boosting governance capacity and offers three mutually nonexclusive solution types that enhance governance support. These solutions support governance by improving the closeness of interactions between the government and the public, the potential for public participation in governance, and the government's own influence. Additionally, the study reveals that innovation can enhance the impact of e-government online services on national governance capacity, thereby providing a more comprehensive perspective on how e-government online services influence national governance. This study advances our understanding of how e-government enhances a nation's governance capability and offers supplementary insights into the fields of interdisciplinary innovation research and mixed-methods research.

Introduction

Online service-based e-government is a relatively new concept that provides value to citizens through streamlined governance processes online (Janowski et al., 2018). This concept has sparked widespread interest among not only practitioners and scholars but also policymakers. It is crucial for enhancing a nation's government's governance capacity. Globally, many governments have taken strong measures to implement online platforms to improve governance transparency and flexibility. Some studies emphasize the benefits of doing so, as it not only reduces government costs but also stimulates innovation through stakeholder participation (Janssen & Estevez, 2013). In particular, as public services transition from offline to online, e-government online service platforms can enrich public service delivery (Sharma et al., 2021) and serve as a new bridge connecting the government and citizens (Chan et al., 2021), ultimately leading to better governance .

To measure the governance level of governments, the World Bank has proposed six indicators: voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption (Kaufmann et al., 2011). Numerous studies have demonstrated the positive impact of e-government on these six indicators (Zou et al., 2023). For instance, e-government helps marginalized groups voice their opinions on the political stage, enhances the efficiency of government–citizen communication, and promotes participation, fairness, and quality of governance (Halachmi & Greiling, 2013; LeRoux et al., 2020; MacLean & Titah, 2022; Stratu-Strelet et al., 2021; Williams et al., 2013). Furthermore, it has a positive influence on political stability by increasing public trust (Chan et al., 2021; Myeong et al., 2014) and plays a role in preventing violent crime (Chang et al., 2018; Meijer et al., 2021). The concept of e-government also enhances government operational efficiency (Panagiotopoulos et al., 2019), optimizes the functions of regulatory bodies (Davidavičienė et al., 2018), contributes to the development of a more mature rule of law society (Zou et al., 2023), reduces the likelihood of corruption and abuse of power (Pathak et al., 2009; Schuppan, 2009), and improves governance

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transparency (Asher et al., 2019; Malodia et al., 2021), among other benefits. This series of effects makes e-government an indispensable tool in modern government governance that better meets the needs of citizens, improves government efficiency, and promotes social stability and development. Therefore, the development and application of e-government hold great significance in today's political and social environment.

E-government is defined as "government agencies using the internet to provide public sector information and online services via the internet" (Shaikh et al., 2016). Although the positive role of e-government in governance improvement has been confirmed in many studies, the results are not clear regarding how e-government online services, as a vital practice within e-government, contribute to governance enhancement.

Furthermore, the role of innovation in this context is often overlooked, with more emphasis placed on the role of innovation at the individual and organizational levels (West & Altink, 1996; Zheng et al., 2021) and less attention given to it at the national level (Ding, 2022). Some perspectives suggest that compared with individuals and organizations, innovation can have a more significant impact at the national level (Karlson et al., 2021). A typical example is the relationship between a nation's innovation capabilities and its capacity to respond to crises, where innovative countries are considered more likely to withstand crises or recover quickly from them (Bristow & Healy, 2018). Another example is the tangible benefits derived from service innovations provided by national governments through e-government. A case study from Indonesia demonstrated that public service innovations organized by the national government can establish online relationships among various elements within a country, thereby significantly enhancing the efficiency and speed of public services (Farida & Lestari, 2021). Research evidence from South Korea, Pakistan, Japan, and Bangladesh showed that innovation can modulate the relationship between knowledge management and the provision of online services, thus helping to form more influential online service provisions (Bokhari & Myeong, 2022).

In fact, service innovation is considered related to the efficiency and quality improvement of public services. Innovation can be utilized to transform inputs into outputs, thereby generating more results and benefits in innovative activities (Iglesias-Sánchez et al., 2019; Zizlavsky, 2016). Research has also demonstrated the complex relationships between innovation and various factors (Ding, 2022), suggesting that innovation should no longer be seen as a linear process but rather as an ecosystem (Bogers et al., 2018). This approach calls for a deeper examination of the interdependence of components in the ecosystem, supporting innovation through mutual interactions (Adner, 2012). An integrated multidimensional perspective helps in understanding the digital ecosystem, particularly with respect to government initiatives promoting digitalization within society (Upadhyay et al., 2022). These integrated factors play a more significant and noticeable role in the national innovation system (Crespo & Crespo, 2016). Thus, whether innovation is considered as a single factor that produces static effects or as a member within a configuration is not sufficient to draw comprehensive conclusions. Thus, the key mechanisms through which innovation operates in this context are still worth further exploration.

In summary, the purpose of this study is to answer two key questions. First, how do online services enhance government governance capacity and provide better support? Second, what role does innovation play as a core concept within this context? Therefore, this study designs a multidimensional and multilevel theoretical framework that first discusses the impact of online services on national governance capacity from dimensions such as the technology level, institutional framework, content provision, service provision, and e-participation mechanisms. It then discusses the impact of innovation on national governance capacity and various aspects of online services to clarify the key mechanisms through which innovation operates.

Given the complex, nonindependent relationships among the various dimensions of online services and between online services and innovation, qualitative comparative analysis (QCA) can treat each factor as a member of a configuration, facilitating a better understanding of the interactions among members and the diverse explanatory relationships that affect national governance capacity through combinations of conditions. However, this method is not detailed enough when analyzing the necessity of a single condition and does not specify the extent to which a condition is necessary. In contrast, necessary condition analysis (NCA) treats each factor as a single factor that produces a static effect, providing a method to assess the intensity and necessity of a single condition's impact on outcomes, which perfectly compensates for the abovementioned deficiency. The NCA method can further help reveal the impact of different factors in the entire online service system as single factors producing static effects, identify which factors need to meet what level of requirements to form necessary conditions for results, and offer perspectives that are different and complementary to QCA (Torres & Godinho, 2022; Vis & Dul, 2018). Therefore, this paper combines the NCA and QCA methods to complete the main part of the research.

The rest of the article is structured as follows.

Section 2 introduces a comprehensive theoretical framework to elucidate how technology, the institutional framework, content provision, e-participation, and service provision impact government governance capacity. It also explains the vital role that innovation can play as a significant driver in this critical process. Section 3 outlines the research methods, research data, and how data reduction techniques were employed to achieve data integration. Section 4 presents the results of the QCA and NCA using the integrated dataset, which combines the performance of innovation from 131 countries with the original dataset. This illustrates how the integration of these two analyses results in more in-depth conclusions. Section 5 discusses the theoretical and practical insights derived from this research, as well as the limitations of this work. The final section also suggests some directions for future research.

Theoretical framework

Impact of government online services on governance capacity

Owing to the significant role that government online services play as an integral component of e-government and the positive impact of e-government on governance improvement, this study posits that government online services may similarly influence government governance capacity. The United Nations E-Government Survey uses five indicators to describe the online service levels of different countries. These indicators include technology, the institutional framework, content provision, service provision, and e-participation. However, it remains a question whether these components indeed serve as critical elements affecting governance capacity.

Impact of technology on governance capacity

In the United Nations E-Government Survey, the description of the technical standard focuses on the technical characteristics of websites to assess their performance in terms of user-friendliness. This includes aspects such as ease of navigation, accessibility (considering compatibility with different browsers, devices, and languages), visual appeal, functionality, and reliability (Kaufmann et al., 2011).

However, in the current digital age, innovative technology is no longer limited to a part of website design. Rather, it has become a crucial driver of government governance. The technology acceptance model emphasizes the impact of the practicality and ease of use of technology on its adoption. In the context of e-government, this theory underscores that if citizens find government online services easy to use and valuable for improving their lives, they are more likely to

adopt and engage with these services (Gupta et al., 2021; Karavasilis et al., 2010; Marzooqi et al., 2017; Saleh & Alyaseen, 2023).

Moreover, the application of innovative technology has profound implications for government governance capacity. First, the integration of information and communication technology into bureaucratic and political systems is often seen as having a positive impact, enhancing citizens' political influence, and promoting the emergence of "creative citizens". Second, by improving the data collection and analysis processes, innovative technology can help governments identify problems more accurately, formulate policies, and monitor social trends. Governments can rapidly acquire big data and extract useful insights via advanced analytical tools to better meet public needs and address challenges (Andersen et al., 2010; Gibson et al., 2014; Stratu-Strelet et al., 2021).

Furthermore, innovative technology enhances capacity related to information security and privacy protection. Governments can implement the latest security measures to protect sensitive data, prevent data breaches, and safeguard national security and citizen privacy. Information technology and e-government have become crucial tools for modernizing and improving public governance (Kamolov & Konstantinova, 2017).

In conclusion, innovative technology plays a critical role in enhancing government governance capacity. Therefore, the first proposition can be stated as follows:

P1: High technological levels are a necessary condition for achieving high governance capacity.

Impact of the institutional framework on governance capacity

In the United Nations E-Government Survey, the institutional framework level is used to measure a city's strategic capacity. This includes the organizational structure of municipal departments, contact information, links to institutions, the presence of portal authentication, and legislative information related to information access, data privacy, open data, and security (Kaufmann et al., 2011).

There is evidence to suggest that the administrative structure of the public sector influences the establishment of innovative partnerships and governance (Barns et al., 2017; Van Winden & Van den Buuse, 2017). For example, administrative silos within public organizations and excessive decentralization of power and responsibility between different government levels may hinder collaborative actions among public entities in e-government (Karppi & Vakkuri, 2020). The internal capacity of public sector organizations also determines their level of development and implementation of digital infrastructure and online services (Trencher, 2019; Wang et al., 2019).

Furthermore, the prospects of applying public value theory in e-government suggest that the digital transformation of the government is not merely a technological matter. More importantly, government agencies themselves should play a crucial role in overall national development planning and strategies for public governance transformation and innovation (Zou et al., 2023).

Therefore, the second proposition is stated as follows:

P2: A high institutional framework level is a necessary condition for achieving high governance capacity.

Impact of content provision on governance capacity

In the United Nations E-Government Survey, the content provision level focuses on the availability of essential information required by residents. This not only involves information from city governments but also extends to other core areas widely related to society, such as open data, smart city initiatives, and the application of emerging technologies (Kaufmann et al., 2011).

The content provision level assesses the quality, availability, relevance, and concise presentation of specific information provided on websites. This criterion includes evaluating issues such as access to contact information for municipal organizational structures, access to public documents, and access to departmental information (e.g., health, education, social security, economics, etc.) (Kaufmann et al., 2011).

Existing research emphasizes the importance of e-government online services in content provision, which refers to supporting virtual and physical assets for data storage, sharing, and analysis. Of utmost importance are the quality and security of datasets, as these directly affect the extent to which data can be reused in online services (Abella et al., 2017; Van Winden & Van den Buuse, 2017). The existence of website privacy policies is also part of content provision in e-government online services because it has the potential to improve public perceptions of the government, increase trust, and promote more interactions with the government. Trust in local governments (Kim & Lee, 2012) and ensuring data security and credibility are crucial for promoting e-participation (Afzalan & Muller, 2018; Lin, 2022).

Therefore, the third proposition is stated as follows:

P3: A high content provision level is a necessary condition for achieving high governance capacity.

Impact of service provision on governance capacity

In the United Nations E-Government Survey, the service provision level assesses a set of fundamental services provided by cities through their websites. The focus is on delivering basic online services, including the analysis of online applications and issuance of certificates and licenses, job searches/quotations, e-payments, the ability to apply or register for municipal activities or services online, the submission of forms and reports, service registration, participation in bidding, and e-procurement. Issues related to e-authentication are also addressed in this standard. An additional aspect evaluated in this standard is how municipal governments respond to email requests (Kaufmann et al., 2011).

Service provision in e-government online services refers to the use of information technology, particularly the internet, to enhance government services provided to citizens, businesses, and other government agencies (Schelin, 2007). Providing public services to the public, in addition to policy-making and regulation, is one of the core functions of national governments and has become more convenient and efficient with the influence of e-government online services (West, 2004). Services based on e-government online services are expected to provide sustainability and transparency to meet citizen participation and expectations (Janowski et al., 2018).

Therefore, the fourth proposition is stated as follows:

P4: A high service provision level is a necessary condition for achieving high governance capacity.

Impact of E-participation on governance capacity

In the United Nations E-Government Survey, the e-participation mechanism primarily aims to assess whether relevant online participation mechanisms and initiatives exist, including forums, complaint forms, and online surveys, among others. Other features considered in this standard include the availability of social media, the possibility of sending comments/suggestions/complaints to local governments, and more complex participation initiatives, such as budget participation, online negotiations regarding public policies and services, and the empowerment achieved through codesigning policy options and coproducing service components and delivery methods (Kaufmann et al., 2011).

In this era of technological advancement, the ways in which citizens participate in politics can be enhanced through information and communication technology tools (Afzalan & Muller, 2018; Graziano, 2020; Kim & Lee, 2012). Innovative e-participation mechanisms can enhance the legitimacy of the government by allowing citizens to participate more directly in the decision-making process and feel that their voices are heard. Moreover, public participation can provide more comprehensive policy insights, aiding governments in formulating more representative and effective policies. Robust public

participation mechanisms can help the government better understand the needs and concerns of society, contributing to the reduction in social discontent and instability. Additionally, e-government online services, owing to their low cost, assured anonymity, and global reach to remote areas and marginalized groups, can help overcome some limitations of traditional public participation models (Aitken, 2014; Macintosh, 2004).

Therefore, the fifth proposition is stated as follows:

P5: Excellent e-participation mechanisms are a necessary condition for achieving high governance capacity.

Impact of innovative E-Government online services on governance capacity

While the United Nations E-Government Survey is a valuable resource, it has certain limitations. The survey heavily relies on the coverage of different types of services when assessing a country's e-government online service capacity, which might limit the data performance of high-level countries in the evaluation indicators. Considering a country's capacity as weak in a particular area simply because it has fewer projects in that area is a one-sided approach. This means that even if a country excels in other aspects, its scores in the United Nations E-Government Survey may be restricted if the scope of its online services is narrow. For example, the low scores for Germany and Belgium in the content provision aspect are unrealistic, as they are on par with one of the least developed countries in the world due to prolonged conflict, Yemen.

Therefore, this study needs to introduce new dimensions to better reflect the true levels of various countries and how online services genuinely impact national governance capacity.

Different members of the social system can communicate and adopt each other's innovative results in a process known as innovation diffusion (Rogers, 2010). Adoption and diffusion are important themes in assessing the success of e-government and have received significant attention in recent e-government research (Karavasilis et al., 2010; Zhang et al., 2014). Innovation diffusion theory posits that e-government represents an innovation spread within society. The degree of innovation in one link may be influenced by the degree of innovation in other upstream and downstream links. Macro- and microlevel theories of innovation, such as national innovation systems (Lundvall, 2007; Wang et al., 2021) and the capacity-motivation-opportunity framework (Bos-Nehles et al., 2017), also suggest that innovation depends on the interdependence of multiple factors. However, most existing conceptual frameworks lack a consensus on the nature of innovation (Fagerberg & Srholec, 2008) and consider only limited entities of innovative activities from a singular perspective (Ding, 2022). Innovation should involve interactions among multiple factors. These interactions also accelerate the emergence and development of innovation (Hekkert & Negro, 2009).

For e-government, particularly in the domain of online services that rely on technological innovations, innovation diffusion is crucial for public services (Hartley, 2005). Some studies have also demonstrated a link between the degree of urban innovation and the likelihood of providing online government services (Bokhari & Myeong, 2022). For e-government online services, innovation can serve as an additional critical dimension that interacts with existing dimensions and can profoundly impact the development of e-government online services (Lythreatis et al., 2022; Sjödin et al., 2020; Torre, 2018).

As described above, various aspects of online services may act as important factors that interact with each other to impact governance capacity. Innovation can make these impacts more pronounced. Fig. 1 illustrates this conceptual framework.

Therefore, this study proposes the sixth and seventh propositions as follows:

P6: A high level of innovation is a necessary condition for achieving high governance capacity.

P7: Innovation can enhance the impact of e-government online services on improving national governance capacity.

Research design and methodology

Methodology

To demonstrate and test the above propositions, this study utilizes qualitative comparative analysis (QCA), necessary condition analysis (NCA), and principal component analysis (PCA) methods.

QCA originated from the exploration of configurational effects. The underlying logic of this method differs from traditional regression analysis's "net effects" approach. QCA is constructed on the basis of Boolean algebra and set theory, making it advantageous for dealing with complex explanatory effects, particularly the interactive effects of multiple factors. However, this method may not provide detailed information about the degree of necessity of a single condition when conducting necessary condition analysis. NCA, on the other hand, can complement this limitation. NCA identifies which factors need to meet what level of requirements to constitute necessary conditions for an outcome. Therefore, the combination of NCA and QCA is more valuable for exploring outcome factors, offering different and complementary perspectives (Torres & Godinho, 2022; Vis & Dul, 2018).

The purpose of this study is to examine the influence and mechanisms of various factors and their combinations in e-government online services on achieving a high level of national governance. Therefore, both QCA and NCA analyses are conducted in this study. Furthermore, since both the QCA and NCA methods accept only one outcome variable and the World Bank provides six indicators to measure government governance levels, a method that can objectively merge data under different dimensions while retaining the ability to reflect data characteristics is needed.

PCA is a method used to reduce the dimensionality of data in deep learning. It attempts to find related indicators in multiple original indicators and then regroups these related indicators into a set of composite indicators to summarize the role of the original indicators.

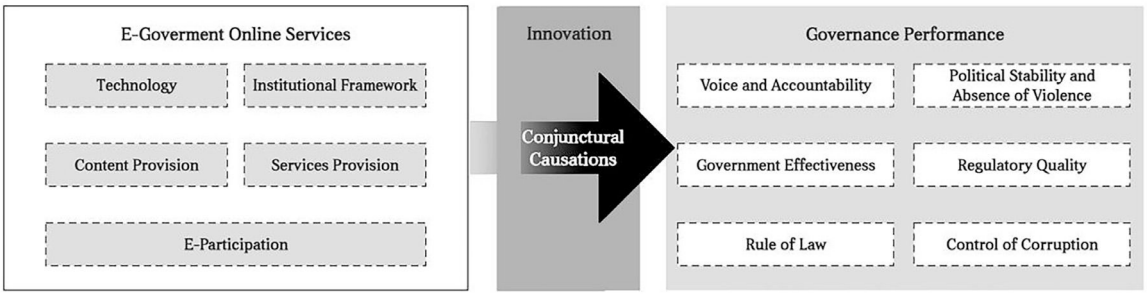

Fig. 1. Conceptual framework.

Owing to the use-agnostic and semantic nature of the data, data can be decoupled from the events they reference and transformed into larger objects (Aaltonen et al., 2021; Alaimo et al., 2020). Using PCA can not only maximally reflect the information represented by the original variables but also ensure that the indicators in the model do not overlap, thus allowing more accurate merging of events referenced by the data. PCA has been widely applied in various fields, such as finance and management (Afees, 2023; Ye et al., 2023). Therefore, this study opts to use PCA as the data processing method to integrate measurement indicators across different dimensions.

Data sources

To select data sources, this study leverages the United Nations E-Government Survey's Online Service Index (OSI), the World Bank's Worldwide Governance Indicators (WGI), and the Global Innovation Index (GII) overall score. Within this framework, the OSI parameters serve as the primary explanatory variables for assessing the specific capacity of online services across countries. The WGI serves as the key outcome variable for measuring national governance capacity.

However, during the construction of the dataset, several issues are encountered. In the UN E-government Survey, each assessed country is assigned scores on the basis of the various target functions or services it provides through its official online e-government service channels. A score of 1 is awarded for each service or function that can be easily accessed and available through the official online e-government service channel. If a target function is missing or inaccessible during the assessment, a score of 0 is given. By answering 180 questions nested under five major categories, a relatively objective and comprehensive evaluation system for online service capacity is constructed.

However, the data obtained through this method may present some issues. First, the evaluation criteria are overly simplified, and an overemphasis on breadth in data performance can result in a lack of depth in reflecting capacity. Second, data lack variability between items. For example, in the case of the content provision level, there are only 10 standard services, resulting in a data precision of only 0.1 (with a minimum of 0.3 and a maximum of 1). This does not adequately represent the differences in performance across different countries in this category.

Building on the theoretical analysis outlined in Section 2 regarding the impact of innovation capabilities and e-government online services on governance capacity, this paper selects the GII overall score as the key indicator for measuring national innovation capabilities, incorporating it into the explanatory variables. Additionally, the hypothesis presented by the diffusion of innovation theory suggests that the significance of innovation in e-government online services is evident not only in its specific capacity but also in its influence on other capacity. This finding indicates that using a comprehensive, generalized indicator of innovation capabilities is more beneficial than employing more specific, detailed capacity indicators. Therefore, this study opts to use the overall score of the GII rather than its individual parameters to explore the mechanisms by which innovation functions within e-government.

Experimental approach

The research objectives of this study extend beyond understanding how online services enhance government governance capacity and provide better support; a significant goal is to clarify the role that innovation, as a central concept, plays within this framework. Consequently, the selection of explanatory and outcome variables in the experiment is crucial.

Both NCA and QCA support the use of multiple sets of explanatory variables while allowing for only one outcome variable. For the purposes of this study, the dependent variable is government governance capacity, and sufficient representative statistical data are currently lacking. Thus, this study uses the World Bank's Worldwide Governance Indicators as the measurement standard. The Worldwide Governance Indicators consist of six data points: (1) voice and accountability, (2) political stability, (3) government effectiveness, (4) regulatory quality, (5) rule of law, and (6) control of corruption. Using the PCA method, these six data points are subjected to feature extraction and dimension reduction, ultimately forming a comprehensive governance capacity index as the dependent variable to better reflect a government's overall governance capacity. Fig. 2 illustrates this process.

Different research objectives necessitate distinct choices in explanatory variables. Consequently, this study establishes both experimental and control groups to conduct NCA and QCA experiments separately. The control group focuses solely on how online services enhance government governance capacity, incorporating only the five elements of the OSI as explanatory variables.

In contrast, the experimental groups require additional considerations regarding the role of innovation from different perspectives. Therefore, in addition to including the GII overall score as an explanatory variable in one part of the experimental group to study the mechanism of innovation from a general perspective, it is also necessary in another part of the experimental group to perform additional data dimension reduction via PCA. This involves integrating the GII

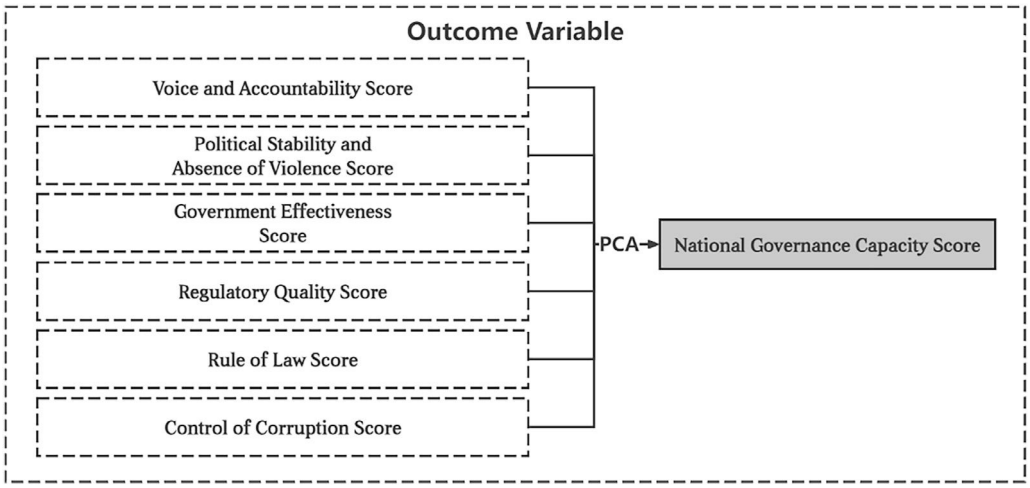

Fig. 2. Construction process of the outcome variable.

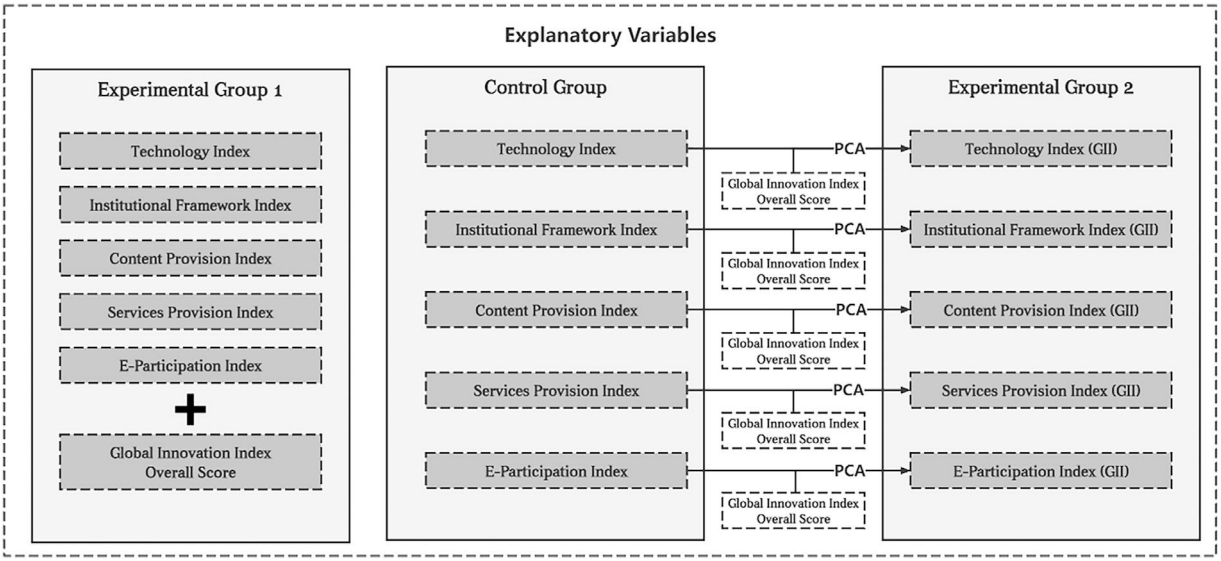

Fig. 3. Construction process of explanatory variables in the control group and different experimental groups.

overall score with different dimensions of the OSI on top of the control group, forming a new dataset with multidimensional characteristics to explore the mechanisms of innovation from an integrated perspective. Fig. 3 illustrates this process. In this study, the variables annotated with GII indicate that they are new variables created by overlaying innovation information from the Global Innovation Index via PCA.

Specifically, PCA is used in this study to calculate various predictor variables with the GII overall score, forming new parameters capable of reflecting the innovation level of services in each country. The GII overall score is a significant resource of interest to scholars, business leaders, and policymakers because it covers the essence of intellectual property and other intangible asset types (Lager & Bruch, 2021). Some research indicates that countries with stronger innovation capabilities tend to receive higher ratings in indices measuring e-government technological achievements and the ability to promote technology (Ifinedo, 2012; Schuppan, 2009), which aligns with the results obtained after experimental processing of the data.

In addition to the selection of explanatory and outcome variables in the experiment, data calibration is another crucial step in QCA. QCA accepts calibrated data ranging from 0 to 1. Owing to a lack of substantive knowledge and literature, this study uses a mechanical calibration method. It utilizes the 95th, 50th, and 5th percentiles of the original data for calibration. To prevent the value of 0.5 from being excluded from the truth table, a constant value of 0.001 is added to all values that equal 0.5 (Du & Kim, 2021; Fiss, 2011), which is the most commonly used calibration method.

Analysis results

Principal component analysis (PCA) reliability analysis

The PCA method allows for the integration of multidimensional data without the need to set explicit weights, unlike weighted calculation methods. However, PCA can be seen as a black-box approach that forms complex linear combinations of original data variables, making not only the operations and outcomes during the data transformation process less intuitively understandable but also the interpretation of its results more complex.

To visually demonstrate the differences in outcomes between the PCA method and traditional weighted calculation methods, as well as to validate the reliability of the PCA method in this research context, a comparative experiment is designed. This experiment involves contrasting the OSI data calculated through the weighted method of the United Nations (OSI_UN) with the OSI data processed via PCA (OSI_PCA) in this study. The visual results are shown in Fig. 4.

As shown in Fig. 4, there is a high degree of similarity in the distributions and trends between the two datasets. A further calculation of the Pearson correlation coefficient between the two datasets yielded a coefficient of $r = 0.98$. The closer the absolute value of the Pearson correlation coefficient is to 1, the greater the similarity between the

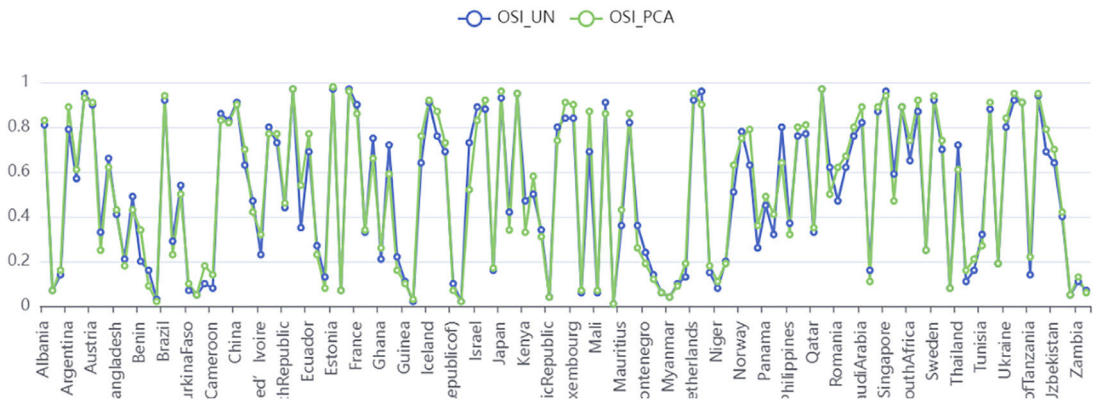

Fig. 4. Differences in data processing outcomes.

Table 1
Analysis of the results of the necessary conditions of the NCA method in experimental group 1.

Condition	Method	Accuracy	Ceiling zone	Scope	D	P values
Innovation	CR	94.7 %	0.175	0.89	0.196	0.000
	CE	100.0 %	0.138	0.89	0.155	0.000
Institutional Framework	CR	98.5 %	0.036	0.87	0.041	0.019
	CE	100.0 %	0.050	0.87	0.057	0.000
Content Provision	CR	90.1 %	0.152	0.88	0.172	0.000
	CE	100.0 %	0.058	0.88	0.066	0.000
Services Provision	CR	95.4 %	0.143	0.90	0.159	0.000
	CE	100.0 %	0.093	0.90	0.103	0.000
E-Participation	CR	92.4 %	0.135	0.90	0.149	0.001
	CE	100.0 %	0.085	0.90	0.094	0.000
Technology	CR	96.9 %	0.092	0.91	0.101	0.010
	CE	100.0 %	0.059	0.91	0.064	0.000

Note: Calibrated membership value of the fuzzy set. Substitution test employed in NCA via a permutation test with 10,000 redraws.

two datasets is, thus indicating the reliability of the PCA method in the research scenario set by this study.

Necessary condition analysis (NCA)

The NCA method focuses on the static effects produced by single factors, identifying which conditions are necessary for outcomes and offering unique insights from the perspective of impact magnitude to support subsequent sufficiency analysis. According to measurement standards provided by Dul and others, a condition confirmed as necessary in the NCA method must meet two criteria: a) the effect size (D) must be greater than 0.1 (Dul, 2016), and b) permutation tests using Monte Carlo simulations must indicate significant test results, meaning that the P values do not exceed 0.01 (Dul et al., 2020). Additionally, when the test results are significant, the influence of the indicators is related to the magnitude of the effect size such that $0 < D < 0.1$ indicates a small impact; $0.1 \leq D < 0.3$ indicates a moderate impact; $0.3 \leq D < 0.5$ indicates a large impact; and $0.5 \leq D < 1$ indicates a very large impact.

NCA employs two techniques to draw ceiling lines, namely, ceiling envelopment with a free disposal hull (CE) and ceiling regression with a free disposal hull (CR). The CR method is suitable when all the independent variables are continuous or discrete and when there are five or more variable levels. On the other hand, the CE method is more suitable for binary variables or discrete variables with fewer than five levels (Dul, 2016). To ensure the rigor of scientific research, this study reports results generated by both the CE and CR methods. However, when conclusions from both methods conflict, this study tends to favor conclusions from the CR, considering the distribution of the experimental data.

Table 1 presents the results of the NCA for the levels of innovation and various online service indicators of government governance capacity. The analysis of the necessary conditions for national innovation levels and individual online service indicators reveals that innovation, content provision, service provision, e-participation, and technology all significantly impact government governance capacity, with innovation having the greatest impact, although it is not significantly different from other factors. The results in Table 1 indicate that only innovation, content provision, service provision, e-participation, and technology are considered necessary, thereby supporting propositions P1, P3, P4, P5, and P6 but not P2.

Table 2 displays the results of NCA for the impact of online service indicators on government governance capacity, which are calculated via the PCA method with overlaid innovation information from an innovation-integrated perspective. The results from Table 2 indicate that the effect sizes for the institutional framework, content provision, service provision, e-participation, and technology level are all greater than 0.1. Additionally, permutation tests via Monte Carlo simulations show that these effects are significant, thereby supporting all propositions P1 to P6.

Tables 3 and 4 further report the results of the bottleneck analysis. The bottleneck level (%) refers to the level value (%) that must be satisfied within the maximum observation range of the explanatory condition to reach a certain level in the maximum observation range of the result. The bottleneck table allows us to make necessary statements in degrees (Dul, 2016). "NN" indicates that, at the current outcome level (Y), the independent variable (X) is unnecessary, and other data capture the degree of change. For example, the analysis of the original data without innovation information indicates that to reach an 80 % level of governance capacity, a country would need to reach at least 45.1 % for innovation, 41.4 % for content provision, 33.5 % for service provision, 36.9 % for e-participation, and 23.5 % for technological innovation. Notably, the level of the institutional framework is found to be unnecessary for reaching an 80 % level of governance capacity.

In contrast, the data analysis with integrated innovation information suggests that to achieve an 80 % level of governance capacity, a

Table 2
Analysis of the results of the necessary conditions of the NCA method in experimental group 2.

Condition	Method	Accuracy	Ceiling zone	Scope	D	P values
Institutional Framework (GII)	CR	87.0 %	0.278	0.90	0.308	0.000
	CE	100 %	0.149	0.90	0.165	0.000
Content Provision (GII)	CR	92.4 %	0.209	0.89	0.234	0.000
	CE	100 %	0.130	0.89	0.146	0.000
Services Provision (GII)	CR	90.8 %	0.246	0.90	0.273	0.000
	CE	100 %	0.145	0.90	0.160	0.000
E-Participation (GII)	CR	90.8 %	0.213	0.88	0.241	0.000
	CE	100 %	0.125	0.88	0.142	0.000
Technology (GII)	CR	96.9 %	0.155	0.90	0.171	0.000
	CE	100 %	0.114	0.90	0.126	0.000

Note: Calibrated membership value of the fuzzy set. Substitution test employed in NCA via a permutation test with 10,000 redraws.

Table 3
Analysis results of the NCA method bottleneck level (100 %) in experimental group 1.

Y	Institutional Framework	Content Provision	Services Provision	E-Participation	Technology	GII
0	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN	NN
30	NN	NN	NN	NN	NN	NN
40	NN	NN	4.3	NN	NN	NN
50	NN	NN	11.6	NN	3.1	7.3
60	NN	13.8	18.9	6.9	9.9	19.9
70	NN	27.6	26.2	21.9	16.7	32.5
80	NN	41.4	33.5	36.9	23.5	45.1
90	19.4	55.2	40.9	51.9	30.3	57.8
100	52	69	48.2	67	37.1	70.4

Note: CR method, NN = unnecessary.

country would need to reach at least 60.2 % of the innovation level for the institutional framework, 52.9 % for content provision, 56.7 % for service provision, 52.8 % for e-participation, and 41.5 % for technological innovation.

The comparison between Tables 3 and 4 reveals that online service indicators, when integrated with innovation information via PCA, exhibit more pronounced levels of impact and bottleneck effects in the NCA and bottleneck analysis. This finding indicates that the government online service evaluation indicators, when innovation levels are considered, have a stronger explanatory relationship with government governance capacity than do standard evaluation metrics.

By conducting a horizontal comparison of the effect sizes calculated via the CR method between the control group and experimental group 2, the results, as shown in Fig. 5, reveal that overlaying the other five factors with innovation information results in a significant increase in effect sizes, with the maximum increase reaching 651.22 %.

This comprehensive analysis demonstrates that innovation significantly enhances the impact of e-government online services on improving national governance capacity, thereby supporting proposition P7.

Qualitative comparative analysis (QCA)

QCA is a set-theoretic method that focuses on the roles played by members in different configurations, enabling the simultaneous analysis of both explanatory conditions and configuration necessity and sufficiency. By measuring the consistency and coverage of the QCA results, it is possible to assess the degree of association and explanatory power between the condition variables and the outcome variable. Table 5 presents the relationships between individual explanatory conditions and high governance capacity in QCA. The explanatory variable is necessary for the outcome variable only when the consistency threshold exceeds 0.9.

The results in Table 5 indicate that the consistency of each indicator is less than 0.9, suggesting that from neither a general perspective nor the perspective of integrated innovation can any single indicator be considered a necessary condition for achieving a high level of governance capacity. Therefore, individual online government service factors alone are not sufficient to form high levels of governance capacity. This seems to differ from the results of the NCA; these differences arise from the different logics used by the NCA and QCA methods (Torres & Godinho, 2022). Such differences can lead to NCA capturing additional necessary conditions compared with QCA (Dul, 2016). However, seeking a single correct result between different NCA and QCA outcomes is erroneous, as they typically provide complementary insights (Ding, 2022; Du & Kim, 2021).

While the single condition necessity tests of the QCA do not find any necessary conditions supporting high levels of governance capacity, the consistency levels of the explanatory variables with innovation information added are consistently above 0.8, indicating greater explanatory power than the original variables. This is consistent with the conclusions of the NCA analysis. Additionally, the consistency levels for the institutional framework, service provision, e-participation index, and technology level variables are all above 0.8, indicating that these four variables provide reliable explanations for high levels of governance capacity. The consistency and coverage levels for content provision are also substantial, indicating its specific explanatory power for the outcome. Furthermore, QCA suggests that high governance capacity levels may result from multiple complex and concurrent explanatory relationships, requiring further analysis of combinations of condition variables to form convincing analytical results.

Additionally, the consistency levels for the institutional framework, service provision, e-participation index, and technology level variables are all above 0.8, indicating that these four variables

Table 4
Analysis results of the NCA method bottleneck level (100 %) in experimental group 2.

Y	Institutional Framework (GII)	Content Provision (GII)	Services Provision (GII)	E-Participation (GII)	Technology (GII)
0	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN
30	5.3	NN	NN	NN	NN
40	16.3	NN	9.2	1.9	NN
50	27.3	10.9	21.1	14.6	NN
60	38.3	24.9	33	27.4	12.7
70	49.2	38.9	44.8	40.1	27.1
80	60.2	52.9	56.7	52.8	41.5
90	71.2	67	68.6	65.6	55.9
100	82.2	81	80.5	78.3	70.3

Note: CR method, NN = unnecessary.

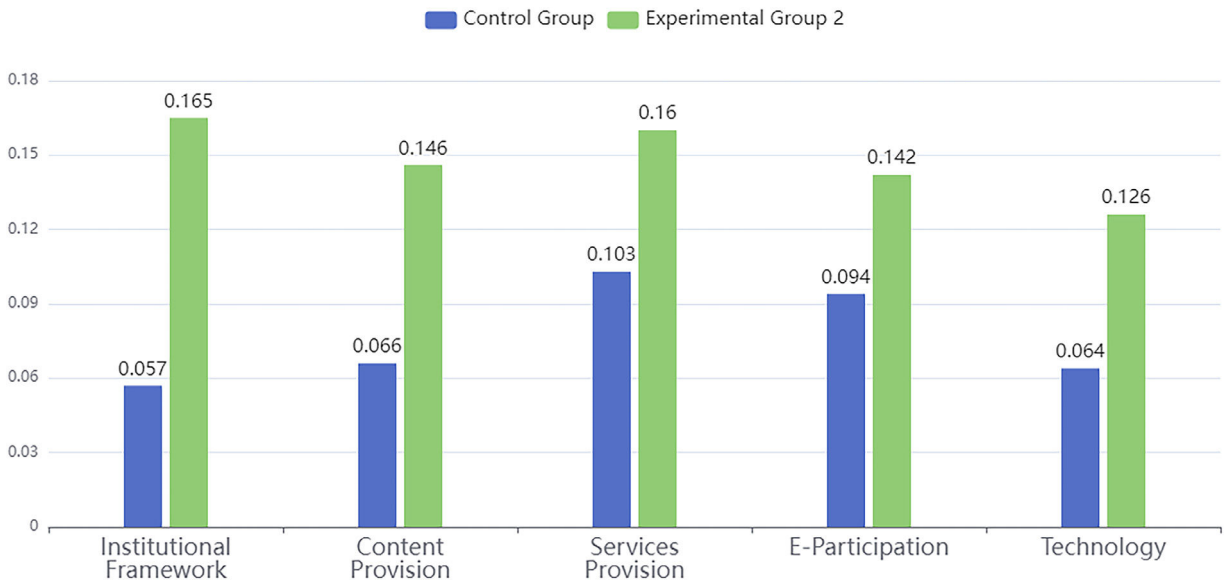

Fig. 5. Comparison of effect sizes from different groups.

provide reliable explanations for high governance capacity. The consistency and coverage levels for content provision are also substantial, indicating its specific explanatory power for the outcomes.

Table 6 shows the configurational analysis results obtained by inputting the original data from the control group into the fsQCA 3.0 software. During the experiment, the frequency and consistency thresholds are set at 1 and 0.8, respectively, on the basis of the specific case sample and past literature references. However, owing to the significant disagreement in the proportion reduction index (PRI) in different experimental settings, combining natural breakpoints, it is set at 0.8, which is higher than the low threshold of 0.6 used in existing research (Ding, 2022; Patala et al., 2021). In addition, by comparing intermediate solutions and simple sets, the core conditions and boundary conditions are identified in different configurations.

Table 5
Analysis of the necessity for high governance performance.

Sets of conditions	Consistency	Coverage
GII	0.842591	0.884362
~GII	0.492367	0.469352
IF	0.834722	0.755919
~IF	0.425513	0.474079
CP	0.786112	0.730821
~CP	0.453492	0.489655
SP	0.819105	0.812499
~SP	0.488196	0.491304
EPI	0.804557	0.826274
~EPI	0.507022	0.49317
TEC	0.8129	0.748705
~TEC	0.465977	0.508674
IF(GII)	0.852722	0.887833
~IF(GII)	0.493849	0.474239
CP(GII)	0.848566	0.872841
~CP(GII)	0.488532	0.47448
SP(GII)	0.856971	0.872965
~SP(GII)	0.489143	0.479493
EPI(GII)	0.838343	0.867356
~EPI(GII)	0.498296	0.481328
TEC(GII)	0.833759	0.880714
~TEC(GII)	0.500436	0.474293

Table 6 presents the conditional configurations S1−S4 for achieving high governance levels. The overall solution consistency is 0.860, which exceeds the acceptable level of 0.75 (Ragin & Strand, 2008), and the coverage is 0.733, indicating that the combined set of results can explain 73.3 % of the cases, demonstrating strong explanatory power.

Recent methodological studies on QCA have suggested obtaining explanatory explanations from parsimonious solutions rather than intermediate solutions (Baumgartner, 2015; Ding, 2022). This is because parsimonious solutions are closer to minimal or nonredundant sufficient conditions, and redundant conditions do not make a difference (Ding, 2022). However, nested comparisons of parsimonious and intermediate solutions remain the mainstream method in current QCA usage, as they can provide richer research conclusions. Therefore, this study bases its core conditions on the solutions provided by parsimonious solutions, which are summarized from the four paths of intermediate solutions, to form two types of solutions for achieving high governance levels: government-public interaction-oriented (configurations S1 and S3) and government-supply-oriented (configurations S2 and S4).

Configurations S1 and S3 emphasize the crucial role of interaction between the government and the public, emphasizing that the institutional framework, service provision, and e-participation are key factors, thus supporting propositions P2, P4, and P5. These factors concern whether the government can effectively receive information conveyed by citizens, which is one of the core strategies of e-government, aiming to "strengthen the interaction between the government and citizens and benefit from e-government services" (Almarabeh, 2011). In theory, incorporating the public participation process into political decision-making can lead to more inclusive and socially acceptable outcomes. Given the complexity of e-government, capturing the unique knowledge and experiences of all residents, which directly impact their daily lives, is crucial (Cooper & Balakrishnan, 2013; Lin, 2022). Successful e-participation depends on factors such as citizens' access to and acceptance of information and communication technology (ICT) and the frequency of use (Aitken, 2014; Tai et al., 2020; Toukola & Ahola, 2022). However, in practice, many factors hinder the process of public participation, such as cultural context, technological literacy, and the opacity of decision-making and processes (Wirtz et al., 2018; Zheng & Schachter, 2017; Zolotov et al., 2018). In some countries, such as Iran, the primary barriers to citizen participation in e-government online services are a lack of awareness

Table 6
Sufficient configurations for high governance performance in the control group.

Configuration condition	S1	S2	S3	S4	Necessity requirement
Institutional Framework	●		●		
Content Provision	•	●		●	
Services Provision	●	●	●	●	>11.6
E-Participation	●		●	•	
Technology		●	•	●	>3.1
Consistency	0.89628	0.885512	0.893306	0.885934	
Raw Coverage	0.630262	0.639767	0.653138	0.64102	
Unique Coverage	0.020003	0.029507	0.042878	0.030761	
Solution Consistency	0.860465				
Solution coverage	0.733409				

Note: The black circles indicate the presence of a condition. Large circles indicate core conditions, and small circles indicate peripheral conditions. Blank spaces indicate 'do not care'.

of their importance, privacy concerns, and the absence of space for public participation (Shahab et al., 2021). In this context, a high institutional framework level and high service provision level are seen as core prerequisites for achieving a high e-participation level. A high institutional framework level provides the public with relevant information on data privacy, open data, and security, enhancing the understanding of e-government decision-making processes and transparency. A high service provision level strengthens the public's ability to participate in e-government services and provides a broader space for public participation.

Therefore, Solution Type 1 is labeled government-public interaction-oriented.

Configurations S2 and S4 consider the proactive nature of government content provision as a core factor. The content provision, service provision, and technology, which serve as core conditions, emphasize that the government, as a provider of online services, must possess specific capacities and qualities. Hence, this supports propositions P1, P3, and P4. Some studies have noted that information and communication technology has the potential to increase the involvement of citizens who are not represented in the current political system (Coleman et al., 2008; Jho & Song, 2015; Stratu-Strelet et al., 2021). Furthermore, performance expectations and convenience conditions brought about by content provision and service provision are also considered powerful drivers of citizens' use of e-participation (Naranjo-Zolotov et al., 2018). As mentioned in Solution Type 1, public awareness directly influences the effectiveness and enthusiasm of public participation in e-government (Aitken, 2014; Tai et al., 2020). Using the internet and online tools to facilitate large-scale public participation in e-government is also promising. It allows the acquisition of local knowledge, promotes the establishment of regional consensus, and improves communication between citizens and the government (Evans-Cowley & Hollander, 2010; Lin, 2022). As seen in Saudi Arabia, if citizens are familiar with and frequently use information and communication technology, e-participation becomes more accessible (Bouregh et al., 2023). In summary, it is essential for the government to actively provide services to ensure that citizens understand the e-participation process, its role, and its significance in national governance (Linders et al., 2018). This is one of the reasons for supplementing Solution Type 1 with Solution Type 2, where a government-supply-oriented development strategy can strengthen the weaker aspects of government–public interaction. Combining the development of the content provision level, service provision level, and technological level provides another effective solution type for countries where conditions make it difficult to directly enhance the e-participation level.

Therefore, Solution Type 2 is labeled government supply-oriented.

To better understand the mechanisms through which innovation operates, the innovation index is reintegrated for further QCA analysis, as demonstrated by experimental group 1 in Fig. 3. The results of this configurational analysis are shown in Table 7.

Table 7
Sufficient configurations for high governance performance in experimental group 1.

Configuration condition	S5	S6	S7	S8	S9	Necessity requirement
Innovation	●	●	●	●	●	>7.3
Institutional Framework	•		•	•		
Content Provision	•	•			◎	
Services Provision	●	●	●		◎	>11.6
E-Participation		•		●	●	
Technology			•	•	•	>3.1
Consistency	0.927998	0.932779	0.916898	0.921377	0.95959	
Raw Coverage	0.628459	0.646949	0.654681	0.659541	0.24312	
Unique Coverage	0.00459957	0.0405252	0.0087254	0.0227686	0.0041258 9	
Solution Consistency	0.91802					
Solution coverage	0.753442					

Note: The black circles indicate the presence of a condition, and '⊗' indicates its absence. Large circles indicate core conditions, and small circles indicate peripheral conditions. Blank spaces indicate 'do not care'.

Compared with Table 6, the overall solution presented in Table 7 has a consistency of 0.918 and a coverage of 0.753, both of which are above acceptable levels and higher than the consistency level of Table 6. Additionally, in configurations S5−S7, service provision serves as the only critical factor other than innovation, aligning with the views presented in S2 and S4. In configurations S8 and S9, e-participation serves as the only critical factor other than innovation, aligning with the views in S1 and S3, thereby supporting propositions P1-P5.

With the inclusion of the innovation factor, the characteristics of the formed path configurations become more pronounced, and innovation serves as a key condition in all paths, indicating that innovation can provide richer information for configurations seeking high government governance capacity, supporting propositions P6 and P7.

However, the research results also indicate that many samples apply to both of these solution types, such as the United States, China, the United Kingdom, France, and other countries. These countries perform well in all indicators, serving as examples of both strong government–public interaction and proactive government service provision. Therefore, further experimentation is needed, combining more information for confirmation.

Table 8 displays the results of the configurational analysis obtained by inputting data, which combines innovation information through PCA, into the fsQCA 3.0 software for experimental group 2. Similarly, 1 and 0.8 are used as frequency and consistency thresholds, with an inconsistency threshold (PRI) of 0.8, which is higher than the existing low threshold of 0.6 used in other studies (Ding, 2022; Patala et al., 2021). Only one conditional configuration that achieves high governance levels is obtained, namely, S10, with a consistency of 0.918 and coverage of 0.777, thus exceeding the acceptable level.

The results in Table 8 further demonstrate that there is a strong explanatory relationship between the various indicators of e-government online services with the added innovation perspective and high governance levels. They emphasize the impact of innovation on a country's governance levels and identifies the final solution type for achieving a high governance capacity level.

The evaluation indicators that incorporate innovation information can more comprehensively assess the performance levels of different countries' governments in various areas and better reflect the profound impact of online government services on a country's governance levels. Configuration S10 shows that a country's high governance capacity level is the result of a multidimensional, collaborative effort. Progress is required in various aspects, such as the institutional framework, content provision, service provision, e-participation, and technology, to drive innovation and more comprehensively evaluate and improve the quality and depth of online services to meet evolving governance needs, thereby supporting propositions P1-P5. Comparisons with configurations S1−S4 and S5−S9 reveal that only in the QCA analysis, which incorporates overlaid innovation information, do all online service factors emerge as key

Table 8
Sufficient configurations for high governance performance in experimental group 2.

Configuration condition	S10	Necessity requirement
Institutional Framework (GII)	●	>27.3
Content Provision (GII)	●	>10.9
Services Provision (GII)	●	>21.1
E-Participation (GII)	●	>14.6
Technology (GII)	●	
Consistency	0.917704	
Raw Coverage	0.777036	
Unique Coverage	0.777036	
Solution Consistency	0.917704	
Solution Coverage	0.777036	

Note: The black circles indicate the presence of a condition. Large circles indicate core conditions, and small circles indicate peripheral conditions.

factors in the configurations, thereby supporting Proposition P7. This finding is consistent with the results of the NCA.

Configuration S10, as the only configuration explaining 77.7 % of the cases, indicates that this path is applicable to the majority of countries and serves as a universal configuration.

Innovation systems must help understand core microlevel behaviors and the "wider environment" within which they operate (Lundvall, 2007). This means that various influencing factors at different levels, including technology, institutional frameworks, content provision, e-participation, and service provision, are subject to and dependent on the existence of an innovation system.

While innovation can encompass various types at the dispersed domain level (institutional, content, service, technology, and e-participation), institutional innovation plays a dominant role in governance innovation because of its direct association with governance effectiveness (Torre, 2018), as the NCA analysis results demonstrate (it has the highest requirement for the institutional framework level). Some research findings indicate that the administrative structure of the public sector influences the establishment of innovative cooperation and governance effects (Barns et al., 2017; Van Winden & Van den Buuse, 2017). The introduction and implementation of innovation solutions are largely influenced by scientific and technological factors, which are commonly referred to as science-intensive drivers. (Almgren & Skobelev, 2020), and technological innovation plays a significant role in enhancing data exchange for social innovation (Huang et al., 2017; Yoo et al., 2010), which is crucial for accelerating the development and growth of any country (Ifinedo, 2012). Digital service and content design innovation help reduce different forms of digital divides in the environment (Lythreatis et al., 2022; Sjödin et al., 2020). Additionally, some perspectives suggest that e-government's strategic orientation should emphasize a citizen-centric approach rather than technology-driven solution types to build e-government innovative services for resident engagement, avoiding "technological determinism" (Ho, 2017).

Solution Type 3 emphasizes comprehensive innovation to drive the achievement of high governance levels. Compared with Solution Type 1 and Solution Type 2, Solution Type 3 is a comprehensive solution type formed on the basis of a more realistic reflection of a country's actual online service levels to address complex and diverse governance challenges in reality.

Therefore, Type 3 solutions are labeled comprehensive innovation-oriented solutions.

Finally and importantly, QCA, which is based on a configurational comparative method, emphasizes that different combinations of conditions can lead to the same outcome, which is a phenomenon known as "equifinality" (Pattyn et al., 2019). This means that in different environments or contexts, various configurations of factors can effectively produce the same result. This suggests that there may be multiple effective configurations for solving the same problem. Therefore, various configurations may coexist within the same case, reflecting different explanatory logics. Consequently, the relationships between solution types are not mutually exclusive. Moreover, regardless of their frequency of occurrence, all competitive explanations of the three solution types are theoretically equivalent in principle (Schneider & Wagemann, 2012).

Robustness testing

In this study, the frequency and consistency thresholds are set to 1 and 0.8, respectively. The robustness of the results is verified repeatedly within the range of 1 to 2 for frequency thresholds and 0.5 to 0.8 for consistency thresholds. The results remain consistent within this range, indicating that the research findings are robust.

Discussion

Contributions

This study makes significant contributions from several perspectives. First, from a research perspective, this study explores the impact of e-government online services on a country's governance capacity. While many studies have investigated the impact of e-government on governance capacity (Umbach & Tkalec, 2022; Zou et al., 2023), this research differs in that it focuses on crucial online service practices within e-government. Unlike most studies that concentrate on linear relationships within a single domain, this research incorporates innovative dimensions to understand how countries integrate innovation into their online services and, in turn, enhance their governance capacity.

In terms of theoretical contributions, this study collects theoretical foundations that underlie the significant influence of different factors of e-government online services on governance capacity, which is often overlooked in the dimension of e-government research. Moreover, this study identifies three solution types for achieving high-level governance capacity, each of which demonstrates how governments can use e-government online services to establish a more stable and positive foundation for relations with citizens, deliver superior proactive services, and achieve comprehensive development by incorporating innovation. These aspects collectively contribute to enhanced support for governance.

Furthermore, the comparative results of this study indicate that online governance service capacity indicators that incorporate innovation information demonstrate a stronger explanatory relationship with governance capacity than do those that do not incorporate innovation information. This finding shows that innovation can enhance the impact of e-government online services on national governance capacity and that incorporating considerations of innovation capacity can more effectively enhance the national government's understanding of the true state of e-government service components.

Finally, from a practical perspective, this research utilizes PCA for data processing and combines the NCA and QCA methods to analyze the interdependent group effects and explanatory asymmetry of governance capacity affected by e-government (Lacey & Fiss, 2009). This approach provides case-based support for the use of the QCA method and its ability to break the assumption of uniform symmetric explanatory effects in linear regression.

Limitations and future research

While this study offers new insights into the integration of innovation in e-government, it has certain limitations that present opportunities for future research.

First, owing to the challenges in data collection, this study uses an e-government evaluation system developed by the United Nations. Different evaluation systems may provide different perspectives. Additionally, measuring a country's innovation level via the Global Innovation Index (GII) from the World Intellectual Property Organization may not comprehensively and objectively measure a country's innovation capabilities, particularly as reflected in e-government online services.

Second, as innovation is a concept that is difficult to quantify, researchers often have significant discretion in selecting factors for evaluation on the basis of their research purposes. Most existing studies lack consensus on the essence of innovation (Fagerberg & Srholec, 2008); thus, the relationship between innovation and other factors may be viewed from various angles. This study considers only the positive effects of innovation on government online services and does not explore the negative effects or challenges that innovation may bring, which can have adverse effects on the quality of online services.

Conclusion

On the basis of a comprehensive theoretical framework, this study initially theoretically proves that government online services can enhance governance capacity. This finding demonstrates that five evaluation dimensions within e-government online services play crucial roles in improving governance capacity. Through a combination of NCA and QCA, the study reveals three types of mutually nonexclusive configurations for high levels of governance capacity, illustrating how these five evaluation dimensions interact to influence and enhance governance capacity. In summary, this research contributes to interdisciplinary innovation research and the field of mixed-methods research.

Declaration of competing interest

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.

CRediT authorship contribution statement

Yuanyuan Chen: Writing – review & editing, Supervision, Project administration, Funding acquisition. **Zhipeng Chen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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