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ORIGINAL ARTICLE

Public Sector Participation in Innovation Governance: Evidence from the Lolli Strategy Project

Mingjuan Liu[1] · **Gioco Vallarta**[2]

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Abstract

The impact of globalization has caused innovation to be recognized as a crucial means of addressing complex global governance problems. With an increasing number of entities participating in innovation, promoting diverse entities to work together and preventing market distribution failures have become important issues in innovation governance. Unlike most studies focusing on social and market participation, this study emphasizes public sector participation in innovation governance. Individual interviews, process tracing, case study, and case comparison were used to observe the behavioral differences between German and Mexican local governments in the same innovation project but at different governance periods. Based on the organizational action theory, the study yields several key findings. First, public sector participation in the innovation governance process is of equal significance to social and market participation. Second, when there is a higher demand for governance and an embedded innovation model is used for the innovation project, the public sector is more likely to participate in innovation governance consistently due to the influence of innovation empowerment and cost–benefit leverage. The authors aims to fill a research gap in public sector behavior by providing a medium and micro analysis framework to explain public sector participation in the innovation governance process, and to improve understanding of innovation governance and contribute to a more comprehensive body of research.

Keywords Innovation governance · public sector · Multi-agent participation · innovation empowerment

✉ Mingjuan Liu
19110170003@fudan.edu.cn

Gioco Vallarta
Vallarta@uni-bonn.de

[1] School of International Relations and Public Affairs, Fudan University, Shanghai, China

[2] University of Bonn, Bonn, North Rhine-Westphalia, Germany

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1 Introduction

The concept of innovation governance first emerged in conjunction with the innovation system proposed by scholars such as Freeman (1987) and Nelson (1993) in the 1980s. In Freeman's (1987) study of Japan's postwar economy, he proposed that a modern national innovation system could stimulate and guide the formation of a network of relationships between science and technology-related entities, which could then be used to promote the emergence, application, and diffusion of science and technology. As an institutionalized relation structure, the national innovation system assisted resource-poor and declining postwar Japan in maximizing resource integration and achieving the innovation development.

During this period, the national innovation systems were referred to as a complex network of relationships, aiming to transform knowledge into beneficial goods within a specific national boundary. The relationship network directs the production, expansion, and application of technology. Building on Freeman's (1987) research, Nelson (1993) emphasizes the important role of government, universities, and other social institutions in innovation activities. In short, innovation is no longer viewed solely as "user–producer interaction, but rather as an interaction of national innovation systems." (Lundvall 1988). The study of innovation system examines the theoretical foundations of innovation governance and contends that economic development and resource endowments are not required conditions for the innovation process. Instead, the effective organization of the innovation system is the starting point for innovation governance.

Globalization has increased the mobility of innovation resources such as capital, knowledge, talent, and technology. At the same time, national policies, ideologies, technological barriers, and other factors cause some innovation projects to shift from a globalized to a closed system. (Yin and Li 2020).Thus, the tension between globalization and closeness has triggered the development of innovation systems with multiple entities. Various innovation entities frequently encounter market allocation failure issues and the collective action dilemma during the innovation governance process (Grossman and Helpman 1990, Gu and Guo 2023, Gu and Guo 2024, Yang and Maskus 2001, Zheng, Zhang and Chen 2020). On the one hand, important innovation projects with low return rates make it difficult to find partners and integrate innovation resources via market allocation mechanisms. On the other hand, due to disparities in interest demand and innovation resource inequality, diversified innovation participants find it difficult to reach an agreement and take collective action.

To avoid market mechanism failure and the dilemma of collective action, innovation governance typically focuses on allocating innovation resources, managing conflicts among innovation stakeholders, and creating a favorable internal and external environment for innovation projects. Although the public sector is not the primary source of new technology and knowledge, it is frequently regarded as a non-dominant participant in innovation governance. However, the public sector is both a key actor in the vertical administrative governance system and an important non-market member of the horizontal pluralistic governance

system. The public sector's dual identity allows it to play a unique mobilization and organizational role in innovation governance as an independent stakeholder. Given the public sector's unique role, the paper's main question is how the public sector chooses to participate in innovation governance. That is, what motivates the public sector to participate in innovation governance?

The study will then focus on explaining the public sector's role in innovation governance. The remainder of the paper is structured as follows. Section 2 reviews relevant studies on innovation governance, organizational action theory, and so on and explain the hypothesis and analysis framework derived from the aforementioned theories. Section 3 elaborates the enhancement and customization of the method. Section 4 provides additional information on both the German and Mexican cases. Finally, Sect. 5 concludes the paper, providing a summary of the preceding content.

2 Literature Review

2.1 Innovation Governance

As previously stated, innovation governance can be traced back to the theory of innovation systems, which consists of various actors involved in developing, organizing, diffusion, and applying new technologies and knowledge. In brief, the governance of the innovation system is known as innovation governance. The main components of innovation governance include rational resource allocation, effective information communication, and the maintenance of an innovative environment, among others. The three most commonly used research theories in innovation governance are network governance, sci-tech centralism, and policy analysis.

First, network governance is a theory that focuses on relationship management, trust, reciprocity, and independent entities. The network is defined as a collaborative structure independent of the market and the hierarchy (Assens and Lemeur 2016). Therefore, applying network governance theory in studying innovation governance tends to exclude public sectors from the hierarchy system. It emphasizes the importance of maintaining the independence of social institutions, research institutions, companies, and third-party organizations. According to Freeman (1987), Lundvall (1992), Nelson (1993), and Edquist (1997), strengthening the network connections between various innovation entities is an important step in innovation governance. Freeman (1987) further concludes that proper guidance and promotion of the link between innovation actors could yield better science and technology innovation results, Nelson (1993) and Edquist (1997) examined the role of the private sector and social organizations, concluding that institutional agents (e.g., planning agencies, universities, and research centers) participate primarily through learning and creativity. Meanwhile, Davis and Eisenhardt (2011), Klerkx and Aarts (2013), and Bai (2020) have argued that third-party institutions are the primary actors in innovation governance. After studying numerous collaborative innovation cases, they tend to suggest that third-party institutions serve as good technology transfer intermediaries in the innovation network, which help remove participant barriers,

reduce transaction costs, and reduce various types of conflicts or opportunistic behaviors in the innovation governance process (Davis and Eisenhardt 2011; Klerkx and Aarts 2013; Bai 2020).

Second, sci-tech centralism emphasizes technology's positive and prominent role in innovation governance. Numerous articles in the field of public administration study the impact of emerging technologies, such as big data, on innovation governance. These studies contend that technological advancements can help improve the efficiency of information sharing and improve the quality and capabilities of innovation governance (Fan, Zhang and Yen 2014; Xu and Ji 2022). In particular, Jun and Chung's (2016) empirical study of the Gyeongsangbuk-do government homepage project in South Korea supports the above view that technology can increase interaction and communication among different innovation actors and help build, maintain, and strengthen relationships within the innovation system.

Finally, policy analysis is a systematic research paradigm that seeks to evaluate and study the formulation, adoption, and implementation of policies addressing public issues (Forrester 1992; Gil-Garcia, Pardo and Luna-Reyes 2018). Policy analysis is based on system, organizational, and behavioral theories, and it promotes empirical research through case comparison and model construction. Without exception, most studies on innovation governance using the policy analysis paradigm are empirical, focusing on comparison and case studies. For example, Bucar and Stare (2009) and Kuhlmann (2001), among others, concluded that the role of public sectors should shift from controller to project partner by comparing the different innovation governance performances of EU and OECD countries. They recommend that public sectors use soft policies (e.g., incentive, advocacy, and institutionalized communication policies) to improve innovation governance performance. In the new diversified era, hard policy instruments are detrimental to the development of governance networks and the efficient flow and rational distribution of core innovation resources. Furthermore, Li, Yan, and Cai (2013), Yang and Feng (2013), Xue (2015), and Thees and Erschbamer (2023) support the preceding conclusions by studying and comparing the innovation governance processes of Finland, Scotland, the United States, France, Japan, Norway, and other countries, they concluded that policy combinations that promote joint governance are more advantageous.

The network governance and sci-tech centrism studies focus more on the positive impact of social institutions, third-party organizations, technology development, and the formation of innovation networks, but all of these studies ignore the public sector. As a non-market actor with public power, the public sector has the potential to significantly impact innovation governance. The role of the public sector in innovation governance has been emphasized in the policy analysis literature; however, policy research simplifies the differences between public sectors and innovation projects, and innovation governance outcomes are attributed to policy as a single factor. Furthermore, the policy analysis study ignores the fact that the public sector does not always participate in the innovation governance process. In brief, understanding the drivers of public sector involvement is critical for motivating the public sector to participate in innovation governance.

2.2 The "Dual Governance Role" and The "Cost–Benefit" of the Public Sector

Before delving into the public sector's role in innovation governance, it is crucial to understand its dual role in the innovation governance system. In addition to supporting the assumption that the public sector should be considered an independent agent with its own interests, it also helps to understand the "costs" and "benefits" of the public sector that will affect its action choice. (Fig. 1).

Vertically, the public sector is the primary executive branch of the administrative system. In general, the public sector cannot act against the will of a higher authority (constitution) and must be accountable to some extent to the superior government (the degree of accountability varies depending on each country's political system; Rong 2014; Malcomsom 1984). The public sector in the administrative system is subject to political pressure from superior government due to the vertical power structure. There are three main political pressure: national policies or laws, budget or financial allocation, and bureaucratic promotion. First, the public sector's primary administrative responsibility is to ensure the implementation of national policies and laws. Second, the budget and financial allocation for various public sectors differ; some public sectors must compete for more financial support. Finally, the promotion and appointment of bureaucrats affect both their personal choices and the public sector's overall performance.

Horizontally, the public sector is the most important political subject in the political process because it interacts directly with society and the market. As the political process theory developed by Easton (1965) specifies, "politics is a systemic process of preference input and policy output." In addition, the public sector is an important political unit that connects political input and output throughout the political system. Therefore, demand expression and political response are the most fundamental interaction processes in the entire political system. As societal and market governance demands become more diverse, the scope of public sector performance is not limited to providing basic public goods but also high-quality public services and timely policy feedback (Husain 2018).

The public sector's dual roles in the vertical administration system and the horizontal political process shape the public sector's own unique costs and

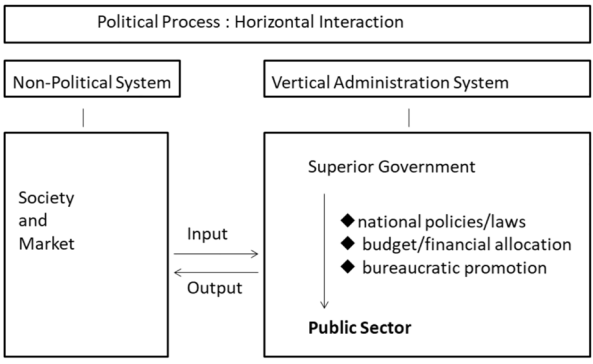

Fig. 1 Dual governance roles of the public sector

benefits, forming the vital premise of this study: the public sector is a stakeholder with its unique cost and interest. (Table 1).

Some scholars classify public sector's costs into five categories: office costs, labor costs, management costs, frictional costs, and hidden costs (Zhuo 2001; Suo and Wu 2003). Meanwhile, other scholars argue that public sector costs are primarily in human, physical, and management costs (Yuan 1998). If we take the public sector's dual role as the starting point, the author holds the view that the primary costs of the public sector are fixed and organizational costs in the innovation governance. First, fixed costs are the basic costs that enable the public sector to perform its functions, such as public employee salaries, infrastructure costs, and information access costs. The fixed costs are proportionate to the size of the public sector and the complexity of its functions. Second, organizational costs include both intra-organizational and extra-organizational costs. Most of the time, intra-organizational costs are related to the structure of political system and departmental barriers, whereas extra-organizational costs focus on the interaction costs between the public sector and other systems outside the political system (e.g., information exchange, benefit negotiation, and resource allocation).

In terms of interest, because the public sector must make decisions and implement policies in a hierarchical administration system, the incentives and rewards within the political system will affect the public sector's political and economic gains. On the one hand, the public sector and its director are the beneficiaries of political benefits, which are expressed in the public sector's reputation and the director's potential political promotion. A good reputation and political capital will increase economic benefits because they help to increase the financial budget and human resources available to the public sector, thereby improving the efficiency of public services. More budget and human resources can help optimize the public sector's software and hardware allocation, lowering initial fixed costs while increasing efficiency. Simultaneously, increasing economic benefits will help build a positive reputation and gain political influence through the reward and punishment mechanism in a hierarchical administration system.

To sum up, in the political process, the public sector's interests are concentrated in political gain and economic benefit. First, effective policy and legislative implementation can accumulate political capital and reputation for the public sector. Political capital and reputation are beneficial not only to the future development of the public sector but also to the advancement of senior bureaucrats within it. Second, high-performing public sectors are expected to receive more financial allocations and budgets, as well as improved economic benefits, as a result of the administrative system's reward and punishment

Table 1 Cost–benefit diagram for the public sector

Cost	Benefits
Fixed costs	Political gains
Organizational costs	Economic benefits

institution design. In short, the two major public sector benefits are not completely separate or integrated, but should be analyzed on a case-by-case basis.

2.3 Analytical Framework

To address the question of "what factors motivate the public sector to participate in innovation governance," this study aims to provide a micro-perspective analysis framework based on organizational behavior theory.

The organizational behavior theory is a systematic theory that studies the source, composition, and application of organizational power. It asserts that organizational managers, interests, and power are all important factors influencing organizational behavior. The main arguments of the theory are as follows. First, organizational behavior is a process after bargaining and negotiation; it is a neutral decision-making process that revolves primarily around power (Pfeffer 1992; Pfeffer and Jeffrey 1978; Pfeffer and Salancik 1978). Second, organizational behavior can be understood as self-serving, with rational decision-making as the corresponding mode. According to the rational model, the organizational behavior follows the "rational man" logic (Woodman 1993; Wilson 1996). Third, when an organization's institutionalization is low, the organizational behavior that is detrimental to overall interests is more likely to occur (Gandz and Murray 1980; Allen 1979; Ferris and King 1991; Robbins 1995).

Organizational behavior theory views the public sector's involvement in innovation governance as a dynamic decision-making process. On the one hand, in the previous section, the author explained the public sector's dual identity and clarified the premise that "the public sector is an independent stakeholder in innovation governance." Moreover, the public sector's participation behavior conforms to the rational model proposed by the organizational behavior theory. Therefore, the potential benefits and organizational power shifts driving the participation behavior would be carefully considered and linked to the governance demand variable. On the other hand, as the organization behavior theory points out, a varying degree of organizational level affects the behavior of entities within the organization. Clearly, the innovation model can be a critical variable for determining institutionalization level in the innovation system (Fig. 2).

H1: High governance demand increases the public sector's benefits from participating in innovation governance.

Three types of high governance demands exist in the public sector: those related to national policies, performance appraisal, and social issues. The first two types of governance demands are associated with the public sector's basic political duties in the vertical administrative system, and the third is associated with the public sector's responsive function in the political process. According to the three types of standards, innovation projects that aim to solve the core social issues or conform to national policy are more likely to attract the attention of the public sector and participate in innovation governance. The existence of governance demands does not automatically prompt the public sector to participate in the innovation projects

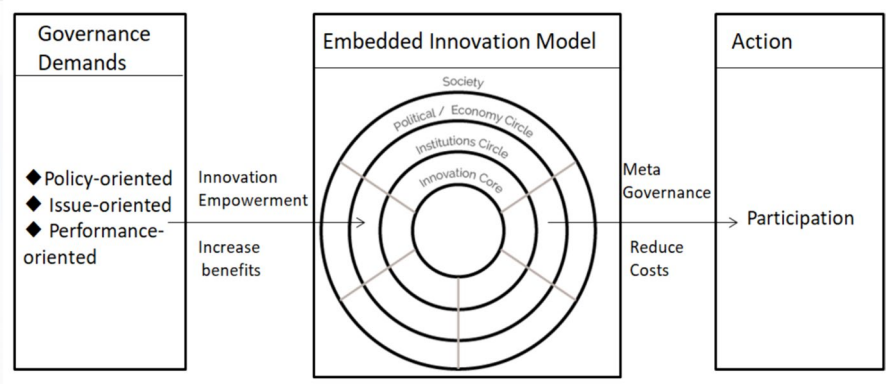

Fig. 2 Governance demands and embedded innovation model

to fulfill its political functions; however, high governance demands increase the benefits of the public sector through innovation empowerment, thus motivating the public sector to participate in innovation governance.

Before explaining the empowerment mechanism, we must first discuss the classification of innovations. Current innovation can be broadly classified into knowledge innovation, technology innovation, and experience innovation. Among such types, knowledge innovation is the foundation of innovation, technology innovation is the breakthrough of innovation, and experience innovation emphasizes the replicability of innovation. (Gloor 2006; Veronica 2007; Zhang and Jiang 2022). Different types of innovation have their own approach to empowering related actors. (Table 2).

First, the meritocracy principle is widely used in modern society, and the importance of knowledge has gradually increased, even when compared with wealth and violence, as an important resource for power transformation. On the one hand, new knowledge will shape a group of experts, and authority can ensure that they have the necessary power resources. For example, technocrats become administrative bureaucrats by mastering new knowledge and subsequently gaining power. On the other hand, applying the "meritocracy" principle in modern society

Table 2 Types of innovation and innovation empowerment

Innovation type	Impact on power
Knowledge innovation	Meritocracy and empowerment of knowledge
Tecnology innovation	Power enhancement and power transfer
Experience innovation	Hidden power

can consolidate and maintain power advantages by accumulating new knowledge and innovation between generations.

Second, the link between technological innovation and power is more obvious. First of all, the birth of new technologies may affect productivity level and further strengthen economic power. Second, the development of new technologies may aid in enforcing norms, thereby consolidating what Foucault (1995) referred to as "disciplinary power." In other words, the use of various new technologies aids in the surveillance, adjudication, and inspection of individuals, requiring them to act following certain standards. Third, new technologies can affect the relative position of individuals, organizations, or states in power relations. For example, when the state attaches importance to scientific and technological innovation, those public sectors associated with the innovation project can gain more financial investment and discretionary power, whereas close or even joint relationships with emerging technology elite groups or business groups can further expand public sectors' power. Technology innovation causes a non-exclusive change in power, and its emergence affects the strength of power and the relative change in the status of power holders and objects.

Finally, experience innovation is more frequently discussed in empirical research or innovation reports, and scholars actively study successful experiences of innovation and attempt to summarize the model for others to emulate. Experience innovation helps to increase the implicit power of innovation actors, and the experience innovation participants have more authority in explaining and spreading specific values, culture, norms, and standards, allowing them to attract more tangible and intangible resources, strengthen their own extraction and mobilization ability, and expand their power by influencing an increasing number of imitators.

In short, when governance demand is high, participation in innovation governance can result in greater political or economic benefits due to the existence of innovation empowerment mechanism.

H2: The embedded innovation model is conducive to reducing the participation cost in innovation governance.

In the West, the governance model has evolved from hierarchy, market, to network governance (Li 2022). However, neither governance model eliminates the possibility of governance failure. Therefore, Jessop (1997) proposed the concept of meta-governance; his research suggests that all governance models should be integrated. Moreover, to achieve excellent governance results, governance actors must choose governance models flexibly in response to changing governance objectives (Jessop 1997). Other scholars developed Jessop's (1997) meta-governance theory and pointed out that the key to meta-governance lies in the following points: first, the core subject of governance must be clearly defined; second, the corresponding governance model should be chosen flexibly; and third, the government or other public sectors should not be excluded from playing a necessary role in the meta-governance process (Jessop 2003, Thompson and Sorensen 2006; Davis and Rhodes 2001, Kooiman J and Jentoft 2009).

During the process of tracing and studying the innovation model of the case named Lolli Strategy Project, the present study finds that in innovation projects

actively participated by the public sector, the innovation model is mostly embedded in the original governance network, and the embedded innovation model conforms to the meta-governance core arguments. The embedded innovation model includes a governance center, but multi agent cooperation and organization processes are quite flexible, and the connections of other governance networks can be institutionalized and used in the embedded innovation system.

An embedded innovation model is an innovation system designed for a specific project and embedded within an inherent governance network. Because of its institutional advantage, the author suggests that the embedded innovation model significantly reduces the public sector's participation costs.

The embedded innovation model's main features are as follows: The first requirement is the existence of an innovation center. The innovation center can be an individual innovator, an innovative organization, the public sector, or even a state or transnational organization. Second, the interaction between the innovation center and other participating actors is based on the existing state and society governance network, which means that the innovation system encompasses stable institutionalized intermediaries. The embedded innovation model forms a "ripple" in the inherent governance network, organizing the entire innovation system in a circle-like outreach. Third, the embedded innovation model exhibits significant flexibility. It can use various social networks, market networks, or hierarchical systems to find innovation collaborators or even replace participants. Moreover, it can alter the innovation governance center to continue the innovation process. (Fig. 3).

Generally speaking, there are two embedded models. One is state-directed embedded model that places the state at the center of the innovation model. This type of embedded model is frequently structured so that each participant is integrated into the national institution system, and the state or government uses its institutional relationship with society or the market to identify and mobilize the appropriate participants to participate in the innovation system. The state-directed embedded innovation model is most commonly applied to innovation projects such as military technology, and national secrecy core science. Another embedding model focuses on the innovative individual or organization and then uses the inherent

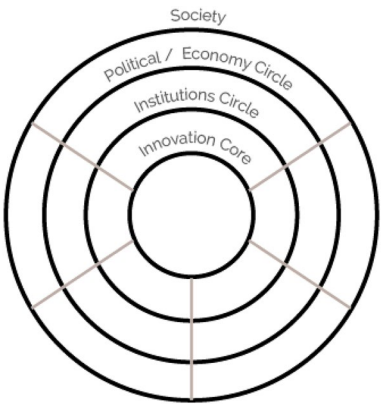

Fig. 3 Embedded innovation governance model (The lines symbolize inherent institutionalized linkages)

individual–organization, organization–organization, and organization–subsystem linkages to form the innovation system. Such interaction and organization fully utilizes the institutionalized interaction of other governance networks, avoiding additional institutionalized costs while greatly facilitating organization and communication within the innovation system.

As Kuhlmann and Edler (2003) points out, innovation governance restructures the relationship between government departments, science, and technology. Therefore, participation in innovation governance is closely related to both the public sector's willingness to participate and the cost of participation.

As shown in Table 1, participation costs in the public sector are broadly divided into fixed and organizational costs. Although the embedded innovation model has a small impact on fixed costs, it has some advantages over non-embedded innovation ones. Especially when individuals or organizations are at the heart of the embedded innovation model, the public sector, as a partner rather than a leader, must provide information, financial assistance, and support for the promotion of a specific innovation project, but the public sector's staff and site costs remain relatively constant.

Second, the embedded innovation model significantly impacts organizational costs in the following two aspects. The embedded innovation model allows for more flexible and effective communication and interaction. Because most innovation models include multiple governance actors with diverse interests and demands, facilitating communication and interaction among multiple governance actors on issues such as benefit allocation, weight balance, and direction coordination becomes an essential component of innovation governance. The embedded innovation model includes both communication channels in hierarchical governance and communication channels between the market, society, and various subsystems; however, a dominant core facilitates effective communication. Second, the embedded innovation model has a more stable structure. The stability of institutionalized intermediaries ensures the long-term stability of the innovation system. Meanwhile, the non-embedded innovation model relies on individuals or specific players to serve as intermediaries between the various governance actors. Only when the intermediary's high organizational capacity can the non-embedded innovation model function reliably. In brief, the embedded innovation model not only values participation diversity but also ensures that communication and negotiation processes are simple. The non-embedded innovation governance model necessitates complex communication at multiple levels, which is unquestionably beneficial to scientific decision-making and interest balance, but it is ineffective for improving innovation governance efficiency and reducing organizational costs.

In summary, the public sector is likelier to choose participation behavior in the embedded innovation model because it reduces fixed and organizational costs. On the one hand, the embedded innovation model enables the public sector, as a member of the innovation system, to easily establish efficient and stable connections with the innovation core via organizational intermediaries. On the other hand, owing to the network of various systems, the public sector has a broad platform for innovation integration and resource extraction in the embedded innovation model, reducing public sector participation costs while enhancing participation ability.

3 Methods and Data

The qualitative methods used in the paper are primarily case study, case comparison, stakeholder interviews, and process tracing. By investigating the development process of an innovation project known as the Lolli Strategy Project during the COVID-19 pandemic in Germany and Mexico, the author can not only observe the entire process of innovation governance but also conduct a comparative analysis of the differentiated public sector participation in the same project over different periods. (Table 3).

Selecting typical cases with high theoretical compatibility is critical in case study and case comparison applications. The Lolli Strategy Project is a biomedical innovation project that began during the pandemic in both Germany and Mexico. The primary reason for selecting this case was its potential to provide insights into innovation governance and public sector participation.

First, in the Lolli Strategy Project's innovation governance process, public sector participation varied both before and after the pandemic's peak and by country. The difference in dependent variables is consistent with the paper's awareness of the problem, and it also provides an excellent "window" into the public sector's participation in innovation governance. Second, Germany and Mexico have relatively similar political systems and administrative structures. Both countries' political structures are based on the principle of separation of powers. Furthermore, both countries are multi-party democratic federal states, with the public sector retaining some independence but its powers not exceeding the scope of the Constitution. The similarity of the political and administrative structures ensures the feasibility of studying various participation actions.

Third, Germany and Mexico have relatively similar levels of human development. The Lolli Strategy project is an innovative medical testing program; hence, the level of human development is the most relevant external environment for this project. The Human Development Index (HDI) 2021 Report classified both Germany (0.94) and Mexico (0.76) as "high level." The data show that despite significant differences in the levels of economic development between the two countries, both governments can provide basic living, healthcare, and education services to their citizens. The Lolli Strategy Project in the Mexican state of Tabasco is similarly focused on developed

Table 3 Governance demands and innovation governance model

	Innovation governance model	
	Embedded model	Non-embedded model
Governance demands		
High	●Continuous participation →German case (before the infection peaks)	●Unstable participation →Mexican case (before the infection peaks)
Low	●Marginal participation →German case (after the infection peaks)	●Non-participation →Mexican case (after the infection peaks)

urban areas as it is in North Rhine-Westphalia, Germany. Given Mexico's extreme wealth gap, the difference in human development levels between the two states' urban areas will be smaller than the national average.

Fourth, Germany and Mexico both adopted the same school shutdown policy to prevent a pandemic, and as a result, local governments in both countries were under much pressure. During the pandemic's most severe period (late 2020 to early 2021), North Rhine-Westphalia and Tabasco closed public schools to control the outbreak. In both countries, where public schools form the majority, school closures affected a large proportion of the educated population and significantly limited population mobility. In Germany, the pressure to close public schools came primarily from parents whose jobs were affected by childcare as well as social groups that emphasized absolute freedom; they exerted pressure on the public sector through the media and social organizations. Social groups and some politicians in Mexico pushed for the closure of public schools due to concerns about inequality. In this context, the Lolli Strategy project, as an innovation project that enables faster infection detection and pandemic control, is beneficial in hastening the end of the shutdown policy. In short, the innovation project has similar appeal to the public sector in both countries.

Furthermore, the author tracked the entire process of the Lolli project's innovation governance in Germany and Mexico, while also conducting in-depth interviews with several key project participants to gather the necessary first-hand information for the case analysis. The majority of the research was conducted in North Rhine-Westphalia (NRW), Germany, and Tabasco, Mexico, where the biomedical project was developed and implemented. In NRW, we conducted a non-participant observation, visiting the university where the project began and observed the work area and activities of the scientific team without directly intervening. This was conducted at the request of the members and to obtain an unbiased perspective on innovation governance. In Tabasco, we visited laboratories and public sector offices to do fieldwork, conduct stakeholder interviews, observe decision-making and communication processes in innovation governance, and collect first-hand information such as field notes, photographs, and videos.

Most interviews were conducted with scientists from the innovation team, support staff from public sectors, and project stakeholders. Key stakeholders in both countries' biomedical projects were identified and interviewed. These participants included founding researchers, leaders, decision-makers, project managers, and operational personnel. The data were then analyzed by compiling field notes, interview transcripts, and reviewing project documents published in both countries to identify emerging innovation patterns and trends, as well as differences in participation action between Germany and Mexico.

4 Case Study

4.1 The Lolli Strategy Innovation Project

The pandemic caused by the SARS-CoV-2 (COVID-19) virus has been a complex global problem. The pandemic had an impact on all social spheres, as well as

economic and social relations worldwide, and it prompted science, technology, and innovation to develop solutions.

Many countries closed schools and day care centers since the beginning of the COVID-19 pandemic to try to reduce infection rates. Only in the first year of the pandemic, more than half of all classes worldwide were cancelled, which had a significant negative impact on children's mental health, socialization, and academic progress. Due to this impact, countries aimed to re-open schools as soon as possible. To this end, the Institute of Virology at the University of Cologne developed a sensitive and child-friendly method using the PCR screening test for detecting SARS-CoV-2 infections in schools and kindergartens, known as the "Lolli Strategy Project."

Prior to 2021, the Lolli Strategy Project was a biomedicine experiment developed by the University of Cologne, with laboratory researchers conducting early-stage pilot tests with funding from the University. Once the principle of medical biology was confirmed in the laboratory, the researchers began to actively seek official support from the governments of Germany and Mexico to continue the pilot phase in order to validate the test. The Lolli Strategy Project received attention and cooperation opportunities from the public sectors in North Rhine-Westphalia (Germany) and Tabasco (Mexico) through the official communication channel between German research institutions and the government and the connections of the innovator team's Mexican researcher. Therefore, the validation and implementation of the Lolli Strategy Project was carried out in both countries.

In 2021, the German and Mexican public sectors participated in the Lolli Strategy Project and provided funding and sample collection assistance, which greatly helped in the completion of the pilot study. The German public sector (Cologne and Solingen governments) approached and participated in the Lolli Strategy Project earlier than the Mexican public sector (Tabasco government) (Fig. 4).

During the Lolli Strategy Project's pilot phase, the North Rhine-Westphalia government provided consistent support for up to 18 weeks, and after the pilot experiment's results were published, the Baden-Wurttemberg and Bayern state governments also supported the project. More than 750,000 children in kindergartens and elementary schools in New Rhine-Westphalia took the Lolli-Methode test as part of the strategy's implementation in May 2021. To meet the demand for tests, a consortium of private laboratories was formed and contracted by the New Rhine-Westphalia government to provide services to state schools. The schools were allocated to the laboratory network based on their location and capacity.

In contrast to Germany's consistent participation in innovation governance, Mexican local governments participated in the Lolli Strategy Project for only 4 weeks. Because local government leaders were unwilling to deviate from their superiors' policy preferences, the Tabasco government's participation in innovation was abruptly halted, dealing a severe blow to the development of the project in Mexico. In short, the Mexican public sector's participation has been unstable. To expedite the project, an innovator from the Institute of Virology made plans to implement the project in Mexico while also validating its quality and sensitivity controls and determining the feasibility of this implementation. Following validation, the Tabasco state government approved and funded the pilot phase,

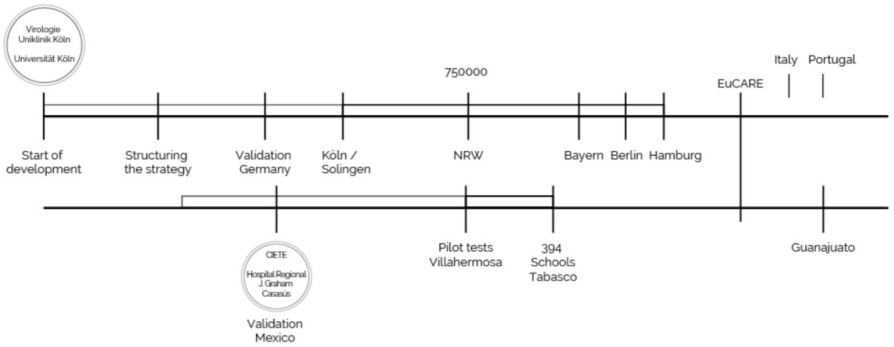

Fig. 4 The Lolli Strategy Project

which was conducted in private schools in Villahermosa and tested attendance rates by class. This pilot phase lasted 1 month and yielded positive results. During the Lolli Strategy Project, three major municipalities in Tabasco, namely, Teapa, Tlacotalpa, and Xalapa, used the effective Lolli test method, with 13,116 people sampled per week in Tabasco state.

4.2 German Case

4.2.1 Governance Demands

In Germany, the arrival of the pandemic infection peak resulted in extremely high governance demands, which were consistent with the author's issue-oriented and performance-oriented situation as described in the theoretical framework.

At a time when there was a high demand for pandemic governance, the German government implemented a number of control measures to address the severe infection situation. On March 12, 2020, Chancellor Angela Merkel met with the 16 regional presidents. The Chancellor advised on closure strategies, and the meeting ultimately decided to implement a staggered closure of schools in each region to deal with the COVID-19 pandemic. To reduce the spread of the virus and protect vulnerable groups, the government announced the closure of schools. It was initially unknown how severe SARS-CoV-2 infection could be in children, so it was a precautionary measure. It was hoped that decreasing the spread of the virus through school closures and implementing social distancing measures would alleviate pressure on the healthcare system.

Following the suspension of classes and the quarantine policy's implementation, Germany faced various governance challenges, including surging economic recession pressures and public discontent pressures. In terms of the economy, close cooperation with other European countries was requested to be established to manage the crisis and implement coordinated measures at the national and European levels. The public also wanted easy access to reliable information about the general pandemic situation without jeopardizing personal data privacy. In a personal interview with the Solingen government's innovation project handover staff, he

stated there was apparent pressure to reopen the schools and deliver test results quickly. The entire German society demanded effective virus detection methods, such as the Lolli Strategy, to contain the virus's spread.

Because Germany has a state-mandated education system and only 9% of students attend private schools, the federal states are responsible for both education and pandemic response. When it became clear that closing schools for so long due to the persistence of infectious diseases was unsustainable, a viable strategy was demanded to avoid outbreaks among vulnerable populations, and the government and public sector must make greater efforts to control the pandemic and improve the detection efficiency of infection cases.

The importance of the pandemic issue has resulted in a surge in demand for governance in the social, economic, and public opinion fields, and the German public sector is also under political and performance pressure from the federal government to address the pandemic's negative impact in the hierarchical administration system. In Germany, power was delegated to a group of federal government officials who issued recommendations, such as Prof. Dr. Christian Drosten, a virologist who served as a government advisor and communicate the new policies implemented in response to the pandemic. The public sector is responsible for implementing the federal government's pandemic control policy recommendations.

The increase in infection cases has significantly impacted Germany's economy, education, healthcare, social security, and other sectors. (Table 4) Controlling the pandemic has become an important political task for the German public sector. To address the most pressing issue, the public sector must seek new detection technologies to improve governance efficiency and meet the policy requirements from the federal government.

4.2.2 The Embedded Innovation Model of Germany

In the case of the Lolli Strategy Project, Germany employs an embedded innovation model, with a core group of innovators. (Figs. 5 and 6) The University of Cologne, acting as an intermediary, successfully connected innovators with the public sector and local governments. The Institute of Virology's innovators began the project by leveraging institutional laboratory resources and talent advantages to develop effective testing methods for vulnerable populations. After passing the first stage and demonstrating the effectiveness of the Lolli Strategy Project, experiments are capitalized, and innovators can obtain additional research funding by expanding

Table 4 Main governance demands for the German local government

Targeted crisis communication	Information and transparency
Lockdown and Restrictions	Contain the spread of the virus
Health policies	Adaptation of health system capacity
Protection of high-risk population	Economic and Financial Problem
Coordinated measures	

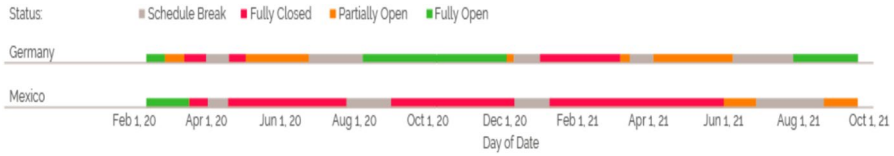

Fig. 5 Innovation networks in the German case (Spreading out with the innovation team at the core)

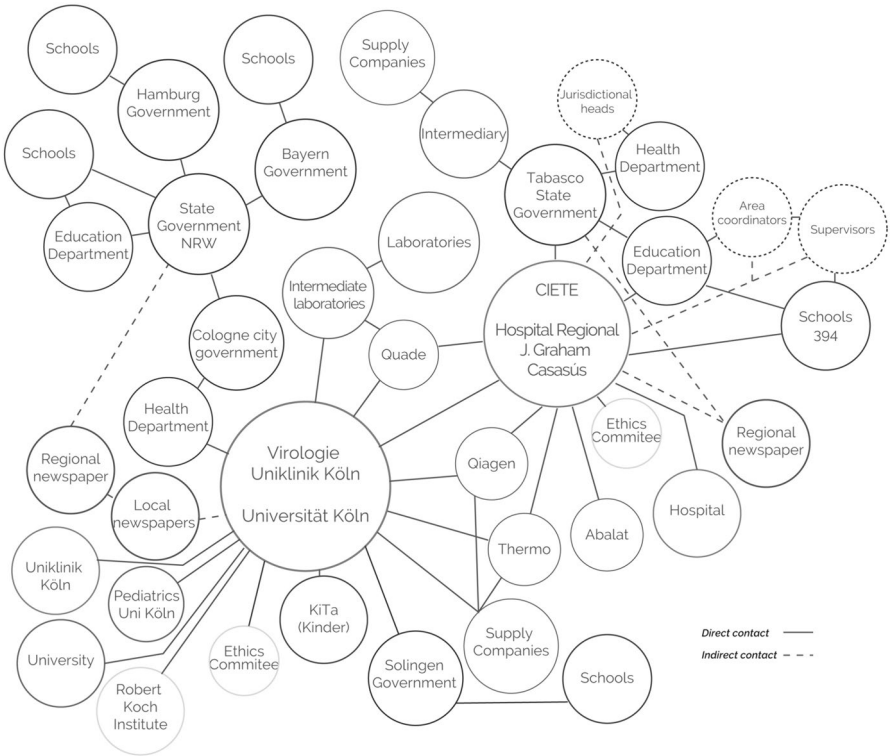

Fig. 6 The embedded innovation model in German case

the innovation system through "institution–university" and "university–Public sector" institutional partnerships. The embedded innovation model, which leverages existing institutional connections to increase innovation participants layer by layer, eliminates the need to re-establish contact channels and reduces additional communication and organizational costs.

For the local governments, the innovative detection technology in the Lolli Strategy Project might improve detection efficiency, which is beneficial to controlling the pandemic in a high governance demand scenario. Joining the Lolli Strategy Project to obtain the right to use detection technology assisted the public sector in better implementing the federal government's pandemic prevention and

control policy and obtaining the high political achievements, political attention, and political capital provided by the new testing technology.

The core of the embedded innovation model is the innovators who created the new testing method; they had some authority in the innovation model but did not have complete control. When the innovation project progresses or changes, the innovator laboratory consults with the University of Cologne before deciding. At the same time, the public sector and other innovation partners would be promptly informed, and the feedback and response process would take place directly between them and innovators via email, WhatsApp, phone, and fax, among others. This improves the efficiency of decision-making and communication processes in the embedded innovation model.

4.2.3 Participation Action of Germany Public Sector

To meet the needs of the German federal government's policy of ending school closures and mitigating the negative impact of the pandemic on all sectors of German society, the German local public sector formed a partnership with a team of researchers from the Institute of Virology, University of Cologne, to collaborate on the development of the Lolli Strategy Project.

When a pilot phase was required to confirm its robustness, acceptance, and feasibility, the public sector and industry collaborated. Because of the public sector's mobilization ability, the initial pilot phase includes approximately 50 daycares and 40 elementary schools from Solingen, Cologne, and neighbor cities. This phase was primarily supported by the governments of Cologne and Solingen, with all tests and logistics conducted in those facilities in collaboration with local governments. Soon after, the Solingen government approved its use in all kindergartens and schools, following the Cologne government's decision.

As the strategy fulfill their claims in May 2021, more than 750,000 children in NRW kindergartens and elementary schools took the Lolli-Methode test (Lolli Strategy). These children underwent two tests per week. To cover the required tests, the NRW government formed and contracted with a group of private laboratories to provide services to state schools. Schools were allocated to the laboratory network based on their location and capacity. The strategy was to continue working for 18 weeks with an average of 26 million samples; more than 1300 SARS-CoV-2 positive classrooms were identified, but no transmission occurred within the school. Three German states (i.e., NRW, Baden-Württemberg, and Bayern) joined the Lolli Strategy Project and implemented the strategy in all schools within their jurisdiction after the research results were published in the Robert Koch Institute epidemiological Bulletin.

As the epidemic peaked and the German local election season approached, innovative pandemic testing became less of a priority in German society, and the Lolli Strategy Project's development slowed. With less public sector involvement in the project, the local German public sector's role has shifted from active to marginal in innovation governance. Based on the embedded innovation model, researchers at the core of the innovation system formed new partnerships with the public sectors in Italy and Portugal via the European Union's institutionalized

intermediary organization. When the demand for governance is low, the flexibility of the embedded innovation ensures the Lolli Strategy Project's survival, and the innovation system can continue to obtain innovation resources from other governance systems and form new partnerships through existing institutionalized intermediaries such as the EU. Even after German local governments have shifted from active to marginal players, the Lolli Strategy Project will continue to improve testing technology for pandemic control and detection.

4.3 Mexican Case

4.3.1 Governance Demands

The outbreak began in Mexico and spread to the Americas as the number of positive cases in Europe increased, and there is a growing demand for disease control in a pandemic-affected society. The high governance demands in Mexico satisfy issue-oriented and performance-oriented situations. On the one hand, the pandemic containment policy has significantly strained Mexico's social, economic, educational, and medical systems. On the other hand, the public sector must urgently achieve outstanding results in preventing and controlling the pandemic to gain political prestige.

Like Germany, Mexico implemented a lockdown policy that resulted in the closure of a large number of schools during the peak of the outbreak. As a young country with an average age of 29 years, school closures reduced people's mobility by up to 60%. Because grandparents used to care for children after their parents leave for work, the policy has also affected older people. However, the Mexican society was unprepared for the school closure policy. The disparity between the wealthy and the impoverished in Mexico is so pronounced that not all households and schools can afford the necessary equipment, such as computers, internet, or devices for online classes, and school closure and other lockdown policies have exacerbated the bottom classes' educational and economic backwardness. In this context, the pandemic has naturally become a top priority, with an increasing demand for innovation governance.

Furthermore, the Mexican economic, social, and healthcare systems pressed the Mexican government to act against the pandemic, putting the government and public sectors under increased performance pressure at all levels (Table 5). Society advocates for those affected to have immediate and equitable access to virus testing and high-quality medical care. It also required financial assistance to mitigate the negative economic impact and transparency in disseminating information about the pandemic. Furthermore, there were numerous flaws in the Mexican healthcare system, and it was feared that it was overburdened, so the government needed to act quickly to meet the demands for adequate infrastructure, personnel, and supplies.

In summary, as the weeks passed, school closures raised serious concerns about the well-being of students, educators, and families, necessitating specific strategies to ensure educational continuity and provide emotional support to affected individuals. By meeting governance objectives and improving governance

Table 5 Main governance demands for the Mexico government

Targeted crisis communication	Information and transparency
Lockdown and flexible restrictions	Contain the spread of the virus
Health policies	Expansion of the healthcare system capacity
Protection of high-risk population	Economic and financial problem
Creation of new non-classroom education modalities	Intergovernmental coordination

efficiency, the new rapid test method of the Lolli Strategy Project eventually drew attention from Mexican local authorities for its ability to assist them in achieving greater political performance and gains.

4.3.2 The Non-embedded Innovation Model of *Mexico*

Unlike the German innovation model, Mexico's innovation model is a non-embedded multi-center overlapping model, rather than an embedded concentric circle. In the Mexican case, there is no single innovation core for promoting the Lolli Strategy Project, and communication and organization among multiple agents rely on informal channels such as personal relationships rather than institutionalized intermediaries.

In Mexico, as professionals (Dr. Hugo López Gatell and Marcelo Ebrad) took the stage, innovators from the University of Cologne actively sought ways to reach out to Mexican public sector leaders, including presenting their project to the Deputy Minister of Health Promotion of Mexico in a preliminary digital meeting. Unfortunately, the Lolli Strategy Project was ignored and received no response from public actors in Mexico. At the operational level, the innovator team found it difficult to find partners in Mexico through established institutions, public cooperation platforms, and social or market networks before the governor personally anticipated the project's potential political benefits. After the public sector joined the project, on the one hand, due to the lack of well-developed multi-dimensional cooperation platforms and public–private networks in Mexico, innovation teams are unable to gain easier access to innovation resources through collaboration. On the other hand, to compensate for the existing system's lack of innovation resources, the public sector had to spend more money to purchase equipment, find experimental sites, and form new teams.

In the non-embedded innovation model, three key individuals play important roles in the Lolli Strategy Project's overall innovation governance process: the state governor, hospital director, and Mexican researcher from the German innovation team. Although the innovation subject owns new technology and knowledge, the innovators team lacked high authority and discourse power in Mexico's innovation system. The innovator team, public sector, and cooperating hospital are relatively independent, and the overall communication occurs through informal means such as personal relationships and notifications. (Figs. 7 and 8).

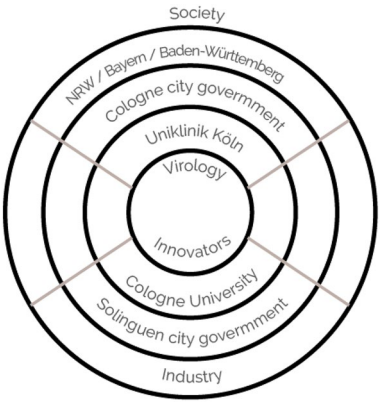

Fig. 7 The non-embedded innovation model in the Mexican case

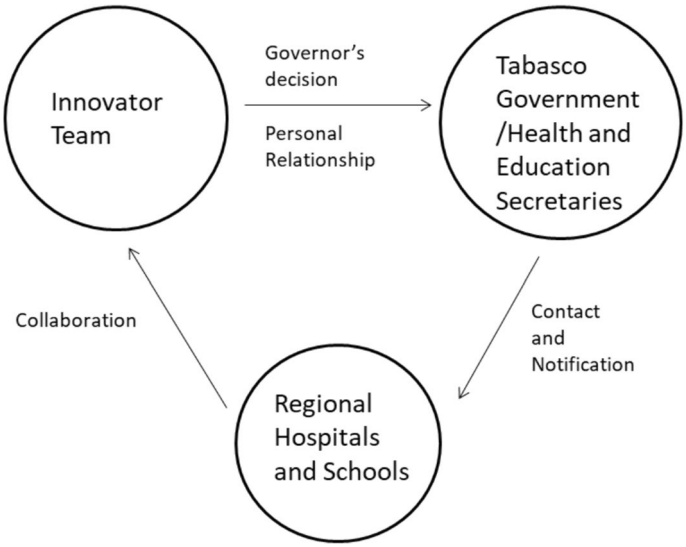

Fig. 8 Innovation networks in the Mexican case (the network is mediated by personal relationships)

In the non-embedded model with multi-center overlap, innovation governance necessitates the creation of a new negotiation mechanism specifically for the innovation project, rather than relying on existing institutions or institutionalized cooperation platforms. When private relationships serve as communication and organizational intermediaries, the negotiation between the public sector, innovators, and other partners becomes complex and two-way. Personal interests, individual preferences, and various system barriers can all interfere with communication results. It significantly reduces information transparency and fluidity and increases participation costs for entities involved in the innovation system.

Finally, the non-embedded innovation model is more vulnerable than the embedded one. Due to the lack of an innovation core, when either entity withdraws

from the innovation project, the innovator team finds it difficult to find other suitable partners quickly. The involvement of the public sector in innovation projects with a non-embedded innovation model not only necessitates additional funding and human resources but also raises the risk that either entity's withdrawal will result in irreversible failure. In fact, when Tabasco's government decided to withdraw from the Lolli Strategy Project, the innovation project suffered a significant setback, with experiments and sampling in Mexico almost completely halted.

4.3.3 Participation Action of *Mexico* Public Sector

Mexico decided in March 14, 2020, that schools should close before or no later than March 20, with some states closing earlier and moving vacation periods earlier, just a few days after Germany did the same. A partial and staggered opening recommendation has been in place until August 31, 2021. Figure 9 shows that there was an 18-month period of uninterrupted closure. Approximately 30% of students missed classes and did not achieve satisfactory learning (UNESCO 2021).

Owing to the personal relationship between the director of the Center for Tropical and Emerging Diseases Research (CIETE) and the Mexican member of the German innovation team, the Lolli Strategy Project formed a partnership with the high-specialty regional hospital in Tabasco (Hospital Juan Graham Casasus), a state in southeastern Mexico. Following validation, the Tabasco state government approved and funded the pilot phase conducted in private schools in Villahermosa to test attendance rates by class. The pilot phase lasted one month and yielded positive results.

Many structures were built in Mexico to support pandemic control, but providing the necessary materials and equipment proved difficult. The local government had to spend more money on expensive experimental equipment and materials to support innovation projects because there is no institutionalized link between the government and other laboratories or research institutions at home or abroad.

In addition to experimental funding, the local government provided the necessary information and convenience for the experiment to occur in Tabasco's three municipalities (Teapa, Tlacotalpa, and Xalapa). While the Lolli Strategy Project was running in Tabasco, 13,116 people were sampled once a week, including students and teachers. According to the calculations, the strategy avoided 2,343 infections.

After one month of implementation, the Lolli Strategy Project was halted due to a lack of reagents and a change in political personnel, and the state government's commitment and support were lost. The governor of Tabasco could no longer support the Lolli Strategy Project because it contradicted Gatell's (Deputy Secretary of Prevention and Health Promotion of Mexico) pandemic management guidelines and previous statements that an excessive number of tests would be ineffective in controlling the pandemic. Despite requests from school teachers, principals, students, and their families to continue the strategy, the funding sources have been abandoned and cannot be renewed. Finally, the Lolli Strategy Project's innovation governance process in Mexico was characterized by instability.

Because there are no readily available institutionalized connections or governance networks to provide available innovation resources for innovation projects, and

Fig. 9 School closure periods (Germany and Mexico)

multi-agent interaction and organization in the innovation system rely on non-institutionalized personal relationships, the public sector's cost of long-term and stable participation in innovation governance is prohibitively expensive.

5 Conclusion

In sum, the paper seeks to address the lack of research on public sector behavior in the field of innovation governance by developing a micro- and medium-scale analysis framework that can explain public sector participation. The paper employs case study, case comparison, and process tracing methods to investigate the factors that drive public sector participation behavior. The author's main viewpoints are as follows:

First, the public sector is not a minor player in innovation governance but an important participant and stakeholder. The public sector is an important unit in the vertical administrative system and a responsive department in the interaction of the political and social/market systems. Due to its dual identity, the public sector must be as sensitive and responsive to societal and market needs as other innovators. As an actor with distinct interests, the public sector's special interests manifest in two ways: political gains and economic benefits. The former primarily involves personnel promotion, political reputation, and political capital, and the latter primarily refers to financial appropriations and special funds.

Second, the author contends that when the innovation mode is embedded and governance demand is high, the public sector is more likely to engage in the governance in a long-term and stable manner. On the one hand, the embedded innovation model promotes the reduction of organizational and communication costs in innovation governance, thereby motivating the public sector to participate in innovation governance. The embedded innovation model is a concentric circle model in which the innovator is at the center and the existing institutionalized channel serves as intermediaries. The existing institutionalized intermediaries can provide participants with the broadest range of innovation resources and information exchange and facilitate communication and coordination among multiple innovation participants and core innovators. On the other hand, when the governance demand is high, the incentives and benefits of public sector participation in innovation governance will be greater. The paper classifies high governance needs into three categories: policy-oriented, issue-oriented, and performance-oriented. Because "meritocracy" is becoming more common in modern society, innovation in knowledge, technology, and experience can accumulate cultural and financial power for innovation participants and provide them with invisible disciplinary power. The greater the need for governance, the more power innovation can accrue to participants.

Third, the empirical research section of this paper compares how local governments in Germany and Mexico participate in the same innovation project. Germany, for example, follows the embedded innovation model, whereas Mexico follows the non-embedded innovation model. The study found that German local governments continuously and stably participated in the Lolli Strategy Project when the demand for governance was higher at the peak of the epidemic. After the epidemic peaked, the need for governance decreased, and German local governments transitioned from active to marginalized participants and from investors to project introducers within the European Union framework. Overall, local government participation in Germany has remained relatively stable. In the case of Mexico, at the height of the pandemic, when governance requirements were high, local governments in Mexico show unstable participation behavior. Because the innovation system's organizational process was based on non-institutionalized personal relationships, decisions made by core politicians and leaders significantly impacted the participation of local governments and the public sector. When the epidemic's peak passed, local governments in Mexico stopped participating in innovative projects and eliminated them entirely. The

difference in local government behavior between the two countries is largely consistent with the theoretical hypothesis of this paper.

However, the paper has certain limitations. The first is the small sample size used in the study, which prevents the generalizability of the conclusions and necessitates additional data analyses. The second is the lack of empirical research on state-led embedded innovation model. The authors have not been able to access core national-level science and technology projects. Finally, in addition to participatory behaviors, there are other diverse behaviors of the public sector in innovation governance that deserve further consideration.

Data availability The relevant data that support the findings of this paper are available in UNESCO at UNESCO Science Report series | 2021 Science Report and UNDP at Human Development Index | Human Development Reports (undp.org).

Declarations

Conflict of interest The authors declare no conflict of interest for this research project. Both authors contributed to the work equally.

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Mingjuan Liu is a PhD candidate in the School of International Relations and Public Affairs, Fudan University. Her research focuses on Governance theory and Comparative Politics.

Gioco Vallarta is a PhD candidate in University of Bonn. Her research focuses on Innovation Society and Systems theory.