frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 27 January 2026
DOI 10.3389/fenvs.2026.1730760

OPEN ACCESS

EDITED BY
Maria Alzira Pimenta Dinis,
University Fernando Pessoa, UFP, Portugal

REVIEWED BY
Zhilei Zhen,
Shanxi Agricultural University, China
Shiran Victoria Shen,
Washington University in St. Louis, United States

*CORRESPONDENCE
Shupeng Lyu,
shupenglv@126.com

RECEIVED 23 October 2025
REVISED 07 January 2026
ACCEPTED 07 January 2026
PUBLISHED 27 January 2026

CITATION
Qian C and Lyu S (2026) Urban sustainability transitions in China: a systematic analysis of the diffusion of sponge city policy.
Front. Environ. Sci. 14:1730760.
doi: 10.3389/fenvs.2026.1730760

Urban sustainability transitions in China: a systematic analysis of the diffusion of sponge city policy

Chen Qian and Shupeng Lyu*

School of Public Policy and Administration, Xi'an Jiaotong University, Xi'an, China

As a new generation of urban water management concepts, sponge city (SC) initiative proposed by China plays the pivotal role in mitigating flood risk, combating climate change, and enhancing environmental resilience. The diffusion patterns and mechanisms of SC policy are analyzed based on the panel data of 263 cities from 2015 to 2020. The results show that the diffusion of SC policy follows an S-shaped curve temporally and involves three distinct stages: local diffusion stage (2015), comprehensive diffusion stage (2016–2018), and saturation diffusion stage (2019–2020). Spatially, the SC policy has diffused predominantly from pilot cities to non-pilot cities and from sub-provincial cities and provincial capitals to ordinary prefecture-level cities, indicating significant neighborhood and demonstration effects. Furthermore, bureaucratic accountability and officials' promotion incentives are key drivers of the diffusion of SC policy. Specifically, a one-unit increase in vertical pressure from the central government, vertical pressure from the provincial government, horizontal pressure, or mayor's age is associated with 7.768, 4.697, 3.074, and 1.039 times higher odds of policy adoption by a prefecture-level city, respectively. Compared to the first year in office, the odds of policy adoption by a prefecture-level city are 1.485 and 1.74 times higher in a mayor's second and third year in office, respectively. However, no comparable association is observed for municipal party secretaries. These findings enrich the theoretical landscape of policy diffusion studies. They further provide critical insights for formulating climate adaptation strategies and advancing sustainable urban transformation in unitary states and multi-tier administrative systems.

KEYWORDS

event history analysis, policy diffusion, policy adoption, sponge city, urban water management

1 Introduction

With continued urbanization and climate change, cities worldwide have suffered severe water problems, such as flooding and water pollution (Mondal and Garg, 2025; Wang et al., 2024). According to the World Meteorological Organization (WMO, 2022), there have been 11,778 disasters attributed to weather, climate, and water extremes over the past 5 decades, resulting in 2,087,229 deaths and economic losses of 4.3 trillion US dollars. In particular, over 90% of reported deaths worldwide occurred in developing economies. As the world's largest developing country, China is particularly confronted with serious urban flooding and water management problems (Ma and Jiang, 2022; Tang et al., 2025). According to the Ministry of Water Resources, flooding disasters have occurred frequently in China over the past decade, resulting in more than 4,400 deaths or disappearances and direct economic losses of more than two trillion Chinese Yuan.

In response, China has launched a national initiative of "sponge city" (hereafter SC) since 2015, which refers to cities that can absorb, store, infiltrate, and purify water during rainfall and subsequently utilize the retained water as required (Mhurd, 2014). As a new generation of urban water management concepts, sponge city construction (hereafter SCC) has experienced a rapid diffusion from initial application in several cities to current widespread adoption nationwide. As of April 2021, i.e., at which point China promoted SCC into the systematic and territorial demonstration stage, 264 prefecture-level cities have adopted SC policy and formulated localized implementation plans aligned with national specifications. The unprecedented passion and rapid response of local governments to SC policy raise an interesting question, i.e., what are the patterns and mechanisms of the diffusion of SC policy? However, relevant research in this regard remains limited. Although there is a considerable body of research on SC, they mainly focus on connotation interpretation (Haase, 2025; Sang and Yang, 2017), problem identification (Wang et al., 2022; Zhou et al., 2025), improvement measures (Dui et al., 2025; Liu et al., 2022), and benefits assessment (Han et al., 2025; Liang et al., 2023). Few studies have systematically investigated the diffusion of SC policy, resulting in little knowledge of the diffusion process.

Conceptually, policy diffusion refers to the process by which a policy or its core components spread among governments via specific channels (Gray, 1973; Lucas, 1983). From Walker's (1969) seminal contribution onward, policy diffusion has been a major research theme in political science and public administration. Numerous studies have focused on democratic decentralized political regimes driven by the metaphor of democratic laboratories and realized many theoretical achievements (Bailey and Karapin, 2025; Berry and Berry, 1990; Shipan and Volden, 2008). As research advances, many studies have applied the policy diffusion theory to the practice of policy innovation in China. Considerable progress has been made in the field of policy diffusion within the Chinese context. The model of autonomous or guided local government innovation experiments has been widely acknowledged as a critical driver of China's economic miracle and regime resilience (Heilmann, 2008; Montinola et al., 1995). Nevertheless, these studies have primarily focused on provincial level administrative licencing centres (Zhang and Zhu, 2018), housing purchase restriction policy (Zou et al., 2022), low-carbon tourism policy (Guo and Li, 2025), new energy vehicle (NEV) financial subsidy policy (Ma et al., 2025), etc. Few empirical investigations have been conducted on the diffusion of SC policy. Given the pivotal role of SC policy in mitigating urban flooding and combating climate change, the ongoing marginalization of this strategically significant policy in the field of diffusion research constitutes a surprising oversight. Indeed, although the field of policy diffusion has generated significant theoretical advancements, the distinctive characteristics of SC policy may restrict the applicability of existing research findings. First, SC policy is frequently perceived as consuming significant fiscal resources and producing limited direct economic benefits. The prevailing cadre appraisal system in China frequently confronts local officials with complex trade-offs regarding the adoption of this policy. Second, public crises, such as extreme rainstorms, experienced by some cities, can facilitate the process of introducing SC. Under China's pressurized system, crisis management often requires rapid policy responses, which means diffusion mechanisms may present different characteristics from conventional models (Meng et al., 2022). Third, previous studies have generally focused on top-down or horizontal pressures. Yet, in practice, some cities (e.g., Anyang) have promoted SCC earlier than provincial counterparts. Thus, the inconsistency between literature and practice underscores the necessity to further identify the determinants and explore how they facilitate or hinder the diffusion of SC policy.

Based on the above analysis, the diffusion of SC policy in China is examined by integrating organizational innovation and policy diffusion theories, so as to fill the gap in the literature. The panel data of 263 prefecture-level cities from 2015 to 2020 is employed to address the following three research questions (RQs). RQ1: What are the temporal characteristics of the diffusion of SC policy? RQ2: What are the spatial characteristics of the diffusion of SC policy? RQ3: What are the drivers of the diffusion of SC policy? Addressing these three questions aims not only to broaden the explanatory scope and applicability of policy diffusion theory in the Chinese context but also to deepen the understanding of the logic underlying local governments' agenda-setting and policy formulation within unitary states and multi-tiered administrative systems. A further purpose is to provide practical insights to support governments and policymakers in facilitating the diffusion and implementation of climate-adaptive and environmental policies, thereby enhancing urban climate resilience and advancing sustainable urban transformation.

The paper is organized as follows. After an introduction of the research framework and theoretical hypotheses in Section 2, the materials and methods are elaborated in Section 3, the results are reported and discussed in Section 4, and conclusions are drawn in Section 5.

2 Research framework and theoretical hypotheses

2.1 Research framework

Based on existing studies and the diffusion practice of SC policy, two key antecedents are identified, i.e., bureaucratic accountability and officials' promotion incentives, which shape the pattern of SC policy diffusion in Chinese prefecture-level cities. Of these, bureaucratic accountability is identified from the external lens, while officials' promotion incentives are identified from the internal lens. The research framework is shown in Figure 1. Details of selection justification and specific hypotheses are explained in the following sections.

2.2 Theoretical hypotheses

2.2.1 Bureaucratic accountability

China is a country with a unitary political system. Its public administration operates within a highly centralized and nested hierarchical structure. Although subordinate governments maintain operational autonomy in the management of public affairs, administrative and personnel systems ensure that superior

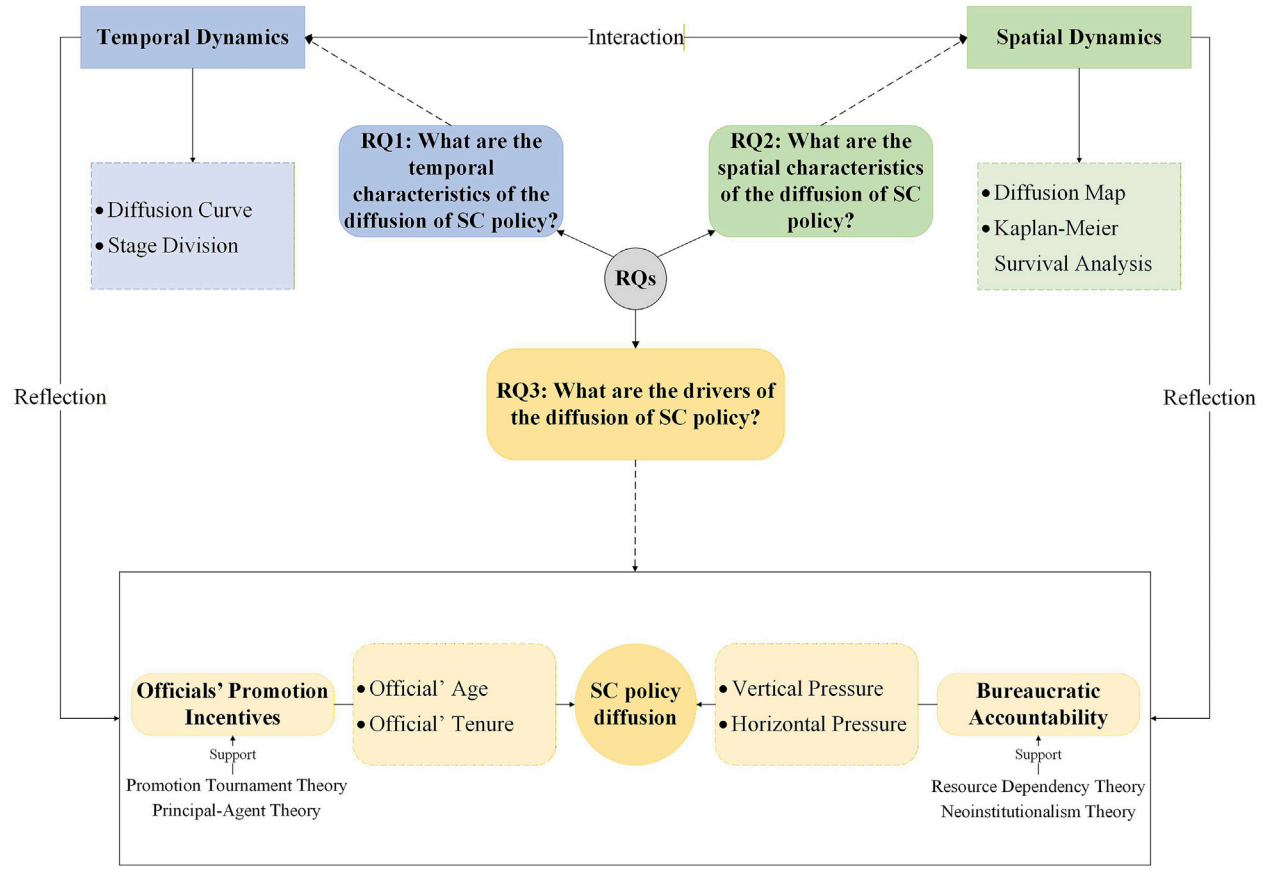

FIGURE 1
Research framework.

governments retain substantial capacity for both incentivized and coercive interventions (Zhu, 2013). Accordingly, subordinate governments may be more concerned with executive efficiency and loyalty to superior governments rather than public interest when crafting policies (Montinola et al., 1995; Shirk, 1993). This inclination critically determines their policy priorities and agenda-setting. Furthermore, the administrative hierarchical structure aligns local governments under a uniform mechanism of evaluation and promotion, fostering intense competition among them (Li and Zhou, 2005). Driven by the dual incentives of political promotion and fiscal benefits, local governments engage in complex strategic interactions, thereby significantly shaping the trajectory and pace of policy diffusion. Hence, when studying the diffusion of policy innovations in China, it is highly desirable and necessary to comprehensively examine the impact of bureaucratic accountability, which primarily involves vertical and horizontal pressures.

With respect to vertical pressures, superior governments have effectively guaranteed accountability and supervision of subordinate governments through institutionalized mechanisms such as personnel appointments and performance assessments. Their preferences not only determine policy direction but also influence policy prioritization and implementation (Shen, 2025a). Supportive signals from superior governments can legitimize a policy innovation by increasing its political visibility and expected benefits (Zhang and Zhu, 2020). Since policy innovation entails political risks and experimentation costs, support from political authorities-especially through pilot programs-provides local governments with valuable room for trial and error, thereby enhancing their willingness to adopt the policy. Furthermore, local governments could demonstrate their loyalty and efficiency to superior governments by actively responding to the policies advocated by the latter, which is beneficial for local leaders' career advancement (Shen, 2025a). Even in the absence of substantive needs for a policy innovation within their jurisdiction, subordinate governments may still adopt it as a ritualistic demonstration of loyalty (Kung and Chen, 2011). In China, vertical pressures on prefecture-level cities mainly derive from the central government and provincial government. Accordingly, the next two hypotheses are proposed:

H1: Pressure from the central government is positively associated with the adoption of SC policy by prefecture-level cities.

H2: Pressure from the provincial government is positively associated with the adoption of SC policy by prefecture-level cities.

With respect to horizontal pressures, on the one hand, motivated by reducing decision-making costs and mitigating potential risks, local governments are inclined to emulate policy innovations of early adopters, even if the actual effects are uncertain (An et al., 2023). Against the backdrop of increasingly intense

regional competition, local governments frequently benchmark themselves against and emulate the policies of their counterparts to maintain competitiveness or avoid falling behind in performance evaluations. On the other hand, the appointment and evaluation of Chinese local officials are overwhelmingly dependent on their relative rather than absolute performance. Relying exclusively on a follower strategy could impede the development of a distinctive competitive advantage. Therefore, local officials with a high level of political will may tend to act as pioneers rather than followers in policy innovation (Shen, 2025b), aiming to enhance professional competitiveness and secure career advancement. Accordingly, two competitive hypotheses are proposed:

H3a: Pressure from other prefecture-level municipal governments is positively associated with the adoption of SC policy by prefecture-level cities.

H3b: Pressure from other prefecture-level municipal governments is negatively associated with the adoption of SC policy by prefecture-level cities.

2.2.2 Officials' promotion incentives

In the context of administrative and fiscal decentralization, the pivotal role of Chinese local officials in the policy-making process and regional development has been widely recognized by academics (Zhang et al., 2025). Under multiple governance tasks and diverse performance appraisal indicators, local officials will continue to adjust the weight of their attention allocation and governance priorities on different policy issues. It ultimately manifests in policy choices, aiming to enhance local officials' promotion prospects. In other words, career advancement concerns largely guide local officials' policy choices. Thus, the promotion incentive of local officials is also key research starting point to properly examine the diffusion mechanisms of SC policy. Given that age and tenure are widely considered critical metrics affecting local officials' promotion incentives, the two indicators are used to construct variables.

With regard to age, there is the phenomenon of the "promotion ceiling" for Chinese officials (Kou and Tsai, 2014). Whereas some countries maintain relatively flexible age limits for local officials (Alesina et al., 2019; Leguizamon and Crowley, 2016), numerous studies have proved that the ineligible age of promotion for Chinese municipal officials is typically 54 or 55 years old (Yu et al., 2016; Wu and Zhou, 2018). At a comparatively early age, municipal officials are in a crucial stage of their career development, characterized by favorable promotion prospects and dynamic career trajectories. With advancing age, especially upon reaching the critical age threshold, municipal officials typically experience a marked deterioration in promotion prospects and career incentives, which induces a fundamental restructuring of their incentive structures. Accordingly, municipal officials' promotion expectations and policy preferences exhibit significant heterogeneity across distinct age groups. On the one hand, with advancing age, the gradual diminishing of promotion incentives for officials may lead to a reduction in bureaucratic efforts to promote economic growth. To prevent recrimination and obtain normal retirement benefits, officials may have a strong incentive to build SC. Simultaneously, prolonged engagement in administrative practice enables officials to accumulate governance experience and establish authority within administrative organizations, thereby providing them with advantages in enacting policy innovation and overcoming implementation resistance. Additionally, as a policy innovation that delivers long-term benefits and aligns with national sustainable development goals, SC may be prioritized by elderly officials seeking to build strong professional reputations. On the other hand, the opposite is also possible. Promotion incentives for officials tend to diminish with advancing age. Traditional economic metrics can be readily translated into tangible performance achievements due to their measurability and visibility. In order to compensate for the decline in promotion prospects, officials may prioritize economic growth in their promotion evaluations, resulting in the excessive pursuit of economic development and neglect of SCC. Moreover, as an emerging paradigm in urban governance, SC necessitates the integration of innovative work and multi-stakeholder collaboration. The advancing age of officials may correlate with a gradual decline in their learning capacity, cognitive adaptability, and receptiveness to innovation, thereby weakening their motivation to build SC. They may demonstrate their aggressiveness in solving water problems as required, but remain focused on economic development.

With regard to tenure, the tenure length of politicians is the key determinant of a wide range of policy outcomes. Chinese municipal officials are usually appointed to a 5-year tenure in accordance with established provisions (Guo, 2009; Zhang et al., 2023), although this is not strictly adhered to in practice. The promotion expectations and career incentives of municipal officials evolve dynamically throughout their tenures, shaped by a combination of individual performance, assessment metrics, and the prevailing political climate. Accordingly, the tenure arrangement enables municipal officials to cultivate differentiated policy preferences and commit to strategic resource allocation programs aligned with their career goals. The prioritization of different policies throughout an official's tenure entails that the implementation of any single policy-regardless of its perceived importance-varies temporally in response to the preferences of either residents or political superiors. Such temporal shifts in implementation create policy waves (Shen, 2022). In a more specific analysis, the diffusion of SC policy is examined. On the one hand, as officials' tenure advances, they may be inclined to explore and implement policy innovations that have not been widely spread, thereby enhancing their promotion prospects under a diverse set of performance appraisal indicators. In order to prevent recrimination and secure retirement benefits, officials may be inclined to assiduously fulfill their fundamental duties, thereby generating a powerful impetus for building SC. Additionally, prolonged service enables officials not only to acquire an in-depth understanding of the local climate characteristics, hydrological dynamics, and infrastructure conditions but also to accumulate greater political capital and social capital. This allows them to better identify policy needs that align with the local context and to reduce implementation barriers for policy innovations, thereby enhancing their initiative to advance SCC. On the other hand, the opposite is also possible. Officials face increasing pressure for career advancement as their tenure advances. By virtue of their measurability and visibility, traditional economic metrics can be readily translated into

tangible performance achievements. In contrast, the benefits of SCC are subject to time lags and externalities, thereby precluding their complete manifestation within the tenure of officials. To seize the dwindling opportunity for career advancement, officials may concentrate resources and efforts on accelerating economic development and neglect SCC. Furthermore, SCC entails technological innovation, engineering management, and multi-stakeholder collaboration. The effectiveness of its implementation is subject to the constraints of multiple factors, including natural conditions, technical capabilities, and coordination mechanisms, thereby introducing significant uncertainty. Out of concern for risk aversion and retirement benefits, officials are likely to maintain a cautious to the point of avoidance attitude regarding this matter.

Accordingly, two sets of competitive hypotheses are proposed:

H4a: The age of local officials is positively associated with the adoption of SC policy by prefecture-level cities.

H4b: The age of local officials is negatively associated with the adoption of SC policy by prefecture-level cities.

H5a: The tenure of local officials is positively associated with the adoption of SC policy by prefecture-level cities.

H5b: The tenure of local officials is negatively associated with the adoption of SC policy by prefecture-level cities.

3 Materials and methods

3.1 Sampling and modeling

In December 2014, three ministries, i.e., the Ministry of Housing and Urban-Rural Development, the Ministry of Finance, and the Ministry of Water Resources, jointly initiated the declaration of the first batch of pilot cities nationwide, which marked the official launch of SCC in China. The selection of pilot cities is conducted through a competitive review mechanism. Cities voluntarily submit applications, after which their eligibility is reviewed by three ministries. For cities that satisfy the eligibility criteria, the three ministries conduct public presentations and expert reviews to determine the final list of pilot cities. In April 2021, the three ministries jointly issued the "Notice on Systematic and Territorial Demonstration of Sponge City Construction", which marked the generalized demonstration of SCC on a national scale. There is no prefecture-level city that adopts the policy for the first time from January to April 2021. Therefore, the time span is set from 2015 to 2020. Considering the fewer years covered, the time interval is set as the month.

The spatial unit is the prefecture-level city. According to the China Statistical Yearbook 2024 published by the National Bureau of Statistics, there are 293 prefecture-level cities in China. After removing prefecture-level cities that did not adopt SC policy and suffered from reorganization of administrative space during the study period, as well as lacked a large amount of socio-economic data, the data sample covers 263 prefecture-level cities. As a result, 7,671 "prefecture-level city-month" observation units are used for analysis in the current research by arranging the event sequence data from January 2015 to December 2020 in 263 prefecture-level cities.

All hypotheses are tested using event history analysis (EHA), which was first introduced into the study of policy diffusion by Berry and Berry (1990). It has now become the most classic and widely used method for analyzing the driving factors of policy diffusion (Liu et al., 2025). Unlike panel data, which considers time and individual fixed effects, EHA uses the data structure of survival data. EHA can deal with the problem of right censoring, as opposed to standard regression techniques that may produce biased estimates. This methodology involves three core concepts. One is the event, which refers to a phenomenon with a relatively clear disjunction between its preceding and following states. The second is the risk set, which describes the collection of individuals in a sample with the "event" within a specific time frame. The third is the risk rate, which is a dummy and dependent variable indicating the probability that an "event" will occur for individual i at a specific time t. Consequently, logistic regression is a well-established and commonly used approach for EHA. The model specification of EHA is classified into two types based on the length of time interval: discrete-time and continuous-time models. Dependent on practical and theoretical reasons, discrete-time models typically use coarser time units (e.g., months or years), while continuous-time models operate on finer time scales (e.g., days). Since the time interval is month, the discrete-time EHA based on logistic regression is employed.

3.2 Variable definitions

3.2.1 Dependent variable

Policy adoption (*Adopt*) is the dependent variable indicating whether a prefecture-level city i adopts SC policy in month t. If a prefecture-level city i adopts SC policy in month t, the dependent variable is assigned a value of one for that month and 0 for all previous months. All data records thereafter are eliminated.

3.2.2 Independent variables

For the dimension of bureaucratic accountability, three variables are incorporated, i.e., the pressure from the central government (*Cen_pre*), pressure from the provincial government (*Pro_pre*), and pressure from other prefecture-level municipal governments (*Peer_pre*). The number of policy documents highly relevant to SCC issued by the central government is taken as the proxy index for *Cen_pre*. Policy adoption by provincial governments is taken as the metric for *Pro_pre*. Furthermore, the proportion of other prefecture-level cities within the same province that have adopted SC policy is used as the evaluation indicator for *Peer_pre*.

For the dimension of officials' promotion incentives, the age (*Age*) and tenure (*Year*) of mayors and municipal party secretaries are included. Indeed, every prefecture-level city has two paramount officials, i.e., the mayor and municipal party secretary. The mayor is the executive officer of the municipal government. The municipal party secretary is the head of the local party committee. As key leaders within the dual-head structure of Party and government, the mayor and the municipal Party secretary together constitute the decision-making core, significantly shaping policy evolution and the development trajectory of prefecture-level cities. Focusing on the

behavioral logic of these two officials can provide a pivotal lens through which to understand the decision-making mechanisms and governance models of local governments within the Chinese context. Furthermore, compared to other municipal officials, the career paths and personal backgrounds of these two individuals are generally more transparent and well-documented, which facilitates data collection and analysis for research purposes. Therefore, the impact of promotion incentives for mayors and municipal party secretaries on policy diffusion is examined. Regarding variable assignment, *Age* is the actual age in the year of employment. A set of dummy variables is used to operationalize officials' tenure in order to minimize *a priori* assumptions regarding the relationship between tenure length and policy adoption. Given that the maximum observed tenure length in the sample is 8 years for mayors and 9 years for municipal party secretaries, creating dummy variables for each year would result in a significant increase in the number of parameters to be estimated. This can consume the model's degrees of freedom, reduce the statistical power of the test, and increase the risk of overfitting. Since 5 years typically represents a standard tenure cycle, all tenures of 5 years or longer are collapsed into a single dummy variable. Specifically, using the first year of tenure as the baseline category, four dummy variables are constructed to represent the second year (*Year 2*), third year (*Year 3*), fourth year (*Year 4*), and fifth or more years (*Year 5*) of tenure length, respectively. The corresponding dummy variable is assigned a value of one if an official is in that specific tenure year, otherwise 0. Regarding the starting point for calculating tenure lengths, the commonly accepted practice in the fields of political science and public administration is followed: if an official takes office on or before June 30 of a given year, his or her tenure for that year is recorded as one; if an official takes office on or after July 1 of a given year, his or her tenure for that year is recorded as 0.

3.2.3 Control variables

On the basis of systematically examining the policy attributes and technical characteristics of SC, as well as referring to the existing research on policy diffusion (Liu et al., 2025; Shipan and Volden, 2006; Zhu and Zhang, 2019), the following control variables are included. Specifically, the key physical and infrastructural variables include: Number of rainstorm days (*Days_rs*), which is estimated as the number of days with 24-h accumulated rainfall exceeding 50 mm. Drainage capacity (*Drainage*), which is calculated by the density of drainage pipes in urban built-up areas. Infiltration capacity (*Infiltration*), which is measured by the green coverage rate of urban built-up areas. Storage capacity (*Storage*), which is measured by the *per capita* water supply. Four variables represent socio-economic conditions: Level of economic development (*GDP*), which is calculated by taking the logarithm of GDP *per capita*. Fiscal dependence (*Finance*), which is measured by the fiscal gap of prefecture-level cities according to Zhang (2015). It is calculated as the difference between budgetary expenditure and budgetary revenue divided by budgetary expenditure. Industrial structure (*Industry*), which is measured by the ratio of the secondary industry to GDP. Public opinion (*Opinion*), which is estimated as the number of news articles on the topic of SC in the Core Newspapers Database of China National Knowledge Infrastructure for each prefecture-level city per year. Additionally, critical spatial and administrative characteristics are controlled for through three variables: Coastal status (*Coastal*), which is measured as a dummy variable for whether or not the city is a coastal city. Coastal cities are assigned a value of 1, otherwise 0. Administrative level (*Level*), which is measured as a dummy variable for whether or not the city is a sub-provincial city or provincial capital. Sub-provincial cities or provincial capitals are assigned a value of 1, otherwise 0. Geographic location (*Local*), which is measured as a categorical variable. Prefecture-level cities in the eastern region are assigned a value of 1, those in the central region are assigned a value of 2, and those in the western region are assigned a value of 3.

TABLE 1 Descriptive statistics.

Variable	Mean	S.D.	Min	Max
Adopt	0.034	0.182	0	1
Cen_pre	0.017	0.131	0	1
Pro_pre	0.536	0.499	0	1
Peer_pre	0.168	0.254	0	0.952
Age_MA	51.447	3.344	40	61
Year 2_MA	0.232	0.422	0	1
Year 3_MA	0.142	0.349	0	1
Year 4_MA	0.178	0.383	0	1
Year 5_MA	0.098	0.297	0	1
Age_PS	53.660	2.865	43	60
Year 2_PS	0.239	0.426	0	1
Year 3_PS	0.187	0.390	0	1
Year 4_PS	0.136	0.343	0	1
Year 5_PS	0.104	0.305	0	1
Days_rs	1.773	2.472	0	17
Drainage	9.248	4.690	0.500	39.350
Infiltration	39.881	5.361	15.400	64.780
Storage	36.878	67.287	2.123	830.013
GDP	4.611	0.260	3.616	5.714
Finance	0.542	0.208	−0.107	0.913
Industry	47.561	8.405	16.090	73.190
Opinion	0.032	0.197	0	3
Coastal	0.160	0.367	0	1
Level	0.076	0.266	0	1
Local	1.972	0.813	1	3

Mean, mean value; S.D., standard deviation; Min, minimum value; Max, maximum value.

3.3 Data sources

Data is compiled from multiple sources. The data on policy adoption and bureaucratic accountability are obtained from the Chinalawinfo Pkulaw Database and government's official web

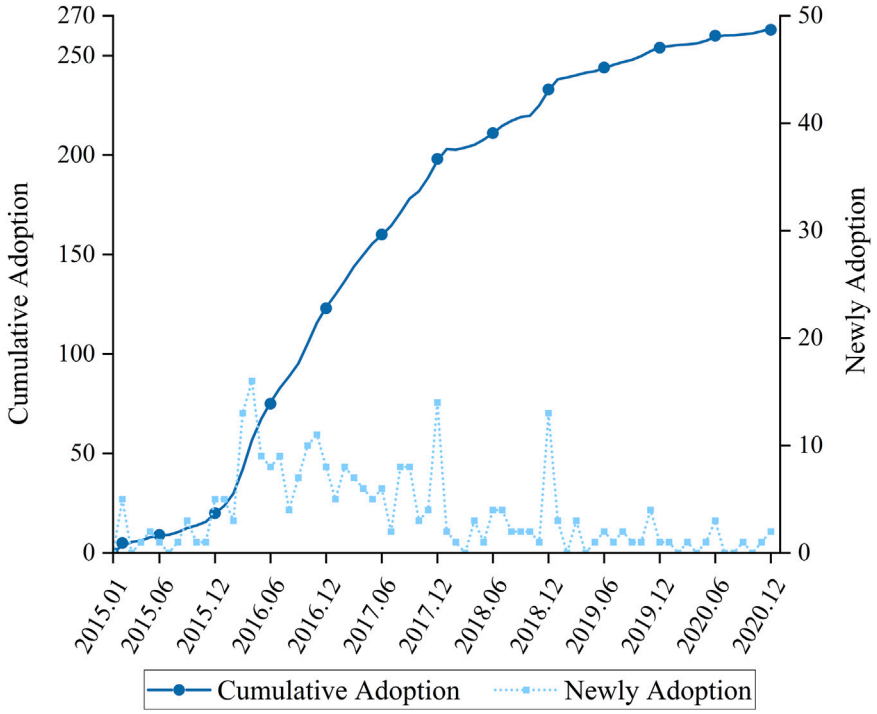

FIGURE 2
Temporal diffusion curve of SC policy.

portal. The personal information of local officials is manually collected from the People's Daily Online, Xinhua Online, and local government websites. Other city-level variables are mainly derived from the China City Statistical Yearbook and China Urban Construction Statistical Yearbook. All value-based variables, such as GDP, are deflated using 2014 as the base period. To eliminate as much as possible the effect of endogeneity issues on the results, explanatory variables are lagged by one period. Table 1 summarizes the descriptive statistics for all variables. All variables contain 7,671 observation units.

4 Results and discussion

4.1 Sketches of SC policy diffusion

4.1.1 Temporal dynamics

The diffusion curve of SC policy is shown in Figure 2. In terms of cumulative adoption, the diffusion of SC policy among prefecture-level cities roughly presents an S-shaped curve, which fits the typical policy diffusion curve (Brown and Cox, 1971; Rogers, 1983). However, this S-shaped curve is steeper than the typical one. That is largely due to the fact that the policy diffusion process is not the incremental policy adjustment by local governments, but rather a "breakpoint" diffusion pattern following intervention by external pressures. It is accordingly divided into the following three stages:

1. Local diffusion stage (2015).

At this stage, the policy adopters are mainly the first pilot cities since the central government holds higher incentives rather than coercion. Other prefecture-level cities are mostly left on the sidelines due to resource constraints and the difficulty of accurately judging the actual benefits of SCC.

2. Comprehensive diffusion stage (2016–2018).

In October 2015, the General Office of the State Council issued the "Guideline to Promote Building Sponge Cities". This implies that SCC has become an essential ecological task for the present and for some time to come, which significantly contributes to the diffusion of SC policy. At this stage, the diffusion of SC policy takes on the characteristic of a blowout, with a total of 214 prefectural-level cities adopting the policy.

3. Saturation diffusion stage (2019–2020).

At this stage, the diffusion of SC policy among prefecture-level cities has basically ended, and the speed of policy diffusion has dropped significantly. Only a few prefecture-level cities, such as Fuzhou, Hulunbeier, and Zhoushan, have just adopted the policy.

4.1.2 Spatial dynamics

Figure 3 illustrates the spatial distribution of prefecture-level cities that newly adopted the policy each year from 2015 to 2020. In 2015, the diffusion of the SC policy across prefecture-level cities exhibits the "multi-point pattern", characterized by near-simultaneous adoption in multiple geographically dispersed locations. From 2016 to 2018, many prefecture-level cities have adopted the SC policy successively. Policy diffusion is predominantly characterized by a combination of neighborhood

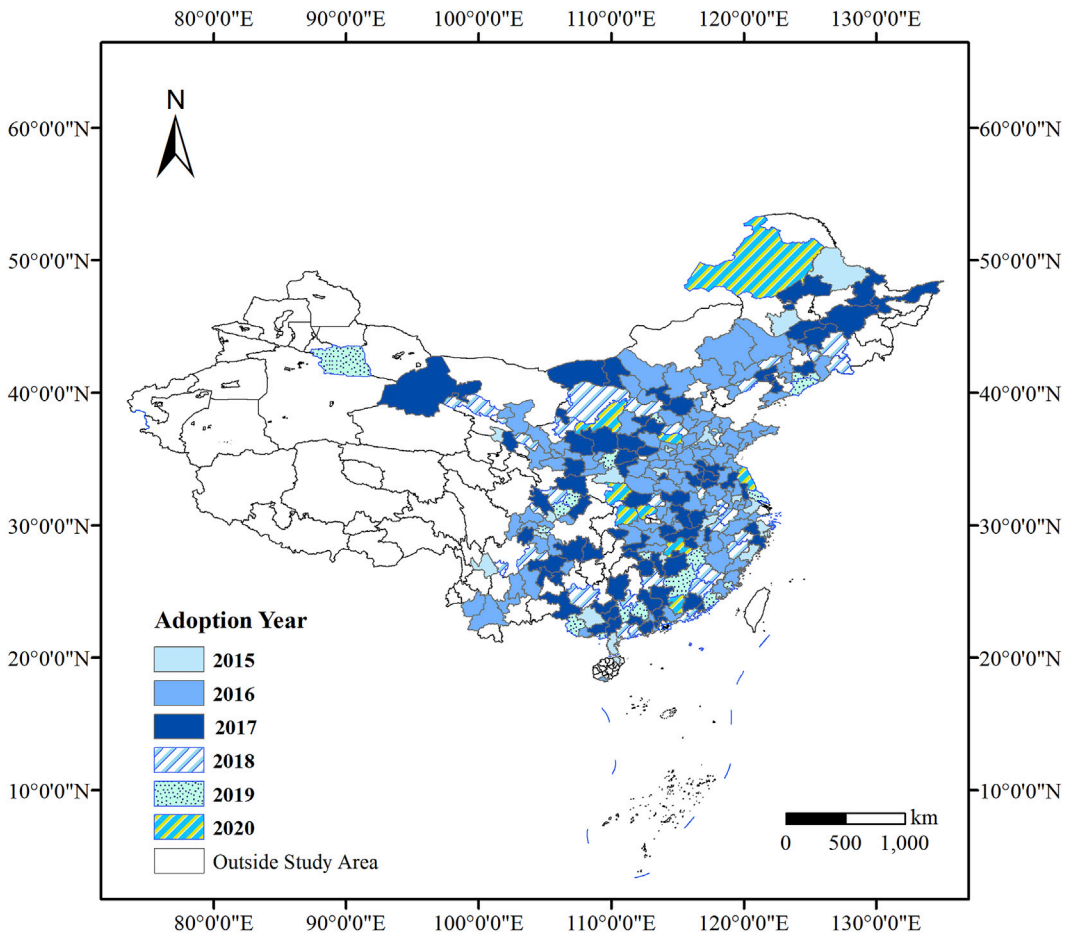

FIGURE 3
Spatial diffusion map of SC policy.

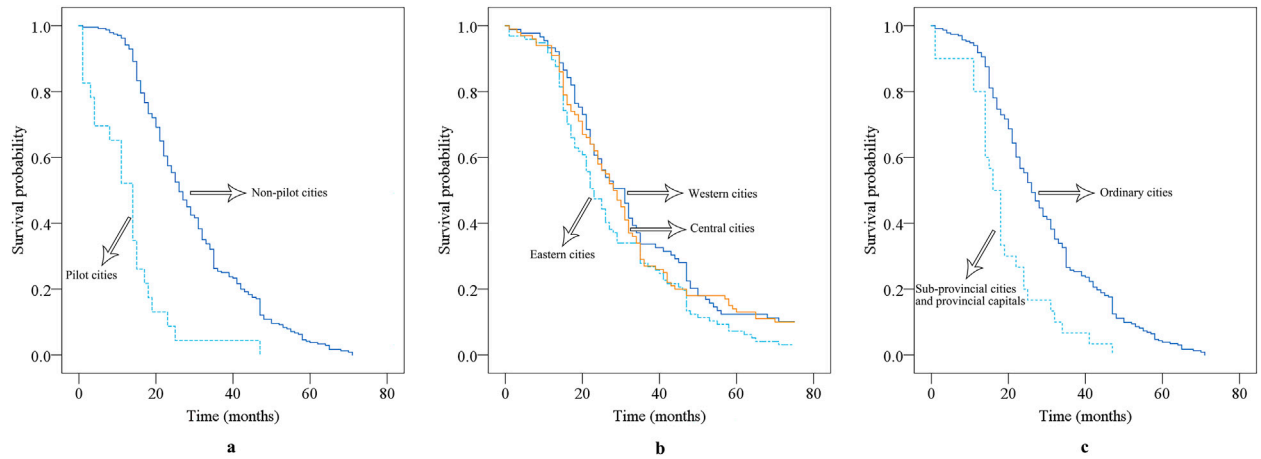

FIGURE 4
Kaplan-Meier survival curves for policy adoption in different prefecture-level cities: **(a)** by pilot status; **(b)** by geographic location; **(c)** by administrative level.

TABLE 2 Results of baseline regression.

Variables	(1)	(2)	(3)		(4)	(5)	
	Coef	Coef	Coef	OR	Coef	Coef	OR
Cen_pre	2.135*** (0.357)	—	2.050*** (0.381)	7.768***	—	2.137*** (0.356)	8.471***
Pro_pre	1.570*** (0.218)	—	1.547*** (0.217)	4.697***	—	1.581*** (0.220)	4.861***
Peer_pre	1.116*** (0.215)	—	1.123*** (0.223)	3.074***	—	1.180*** (0.242)	3.256***
Age_MA	—	0.055*** (0.021)	0.038* (0.022)	1.039*	—	—	—
Year 2_MA	—	0.644*** (0.162)	0.396** (0.159)	1.485**	—	—	—
Year 3_MA	—	0.400* (0.224)	0.554*** (0.215)	1.740***	—	—	—
Year 4_MA	—	0.115 (0.206)	0.241 (0.196)	1.272	—	—	—
Year 5_MA	—	0.268 (0.208)	0.326 (0.205)	1.385	—	—	—
Age_PS	—	—	—	—	0.040* (0.022)	−0.016 (0.029)	0.984
Year 2_PS	—	—	—	—	0.154 (0.167)	−0.029 (0.157)	0.972
Year 3_PS	—	—	—	—	−0.278 (0.216)	−0.048 (0.212)	0.953
Year 4_PS	—	—	—	—	−0.191 (0.210)	0.041 (0.208)	1.042
Year 5_PS	—	—	—	—	0.002 (0.232)	0.301 (0.264)	1.352
Days_rs	0.083*** (0.027)	0.138*** (0.025)	0.077*** (0.028)	1.080***	0.144*** (0.023)	0.081*** (0.027)	1.084***
Drainage	−0.013 (0.015)	−0.010 (0.013)	−0.015 (0.015)	0.985	−0.005 (0.012)	−0.015 (0.015)	0.985
Infiltration	−0.048*** (0.014)	−0.039*** (0.012)	−0.048*** (0.014)	0.954***	−0.037*** (0.013)	−0.048*** (0.014)	0.953***
Storage	−0.006** (0.003)	−0.002 (0.002)	−0.005* (0.003)	0.995*	−0.003* (0.002)	−0.006** (0.003)	0.994**
GDP	0.349 (0.280)	0.637* (0.356)	0.370 (0.295)	1.447	0.687* (0.356)	0.304 (0.281)	1.355
Finance	−1.217** (0.493)	−0.080 (0.454)	−1.234** (0.498)	0.291**	−0.076 (0.438)	−1.259** (0.489)	0.284**
Industry	−0.020** (0.008)	−0.025*** (0.007)	−0.018** (0.009)	0.982**	−0.029*** (0.007)	−0.019** (0.008)	0.981**
Opinion	0.615*** (0.166)	1.208*** (0.127)	0.615*** (0.173)	1.849***	1.197*** (0.128)	0.588*** (0.173)	1.800***
Coastal	−0.475** (0.201)	−0.467*** (0.155)	−0.501** (0.198)	0.606**	−0.476*** (0.163)	−0.408** (0.205)	0.665**
Level	0.524 (0.323)	0.118 (0.201)	0.341 (0.327)	1.406	0.298 (0.195)	0.483 (0.328)	1.621
Local	0.018 (0.096)	−0.023 (0.070)	0.030 (0.096)	1.030	−0.038 (0.070)	0.042 (0.095)	1.043
Constant	−2.845** (1.444)	−6.782*** (2.066)	−5.236*** (1.859)	0.005***	−5.898*** (2.168)	−1.853 (2.158)	0.157
Log likelihood	−1009.494	−1086.275	−1002.882		−1095.137	−1008.250	
Chi-square	233.20***	199.94***	253.18***		216.60***	238.63***	
Pseudo R^2	0.119	0.052	0.125		0.044	0.120	

Robust standard errors in parentheses are clustered at the prefecture-level city level; *, **, *** denote statistical significance levels at 10%, 5% and 1%, respectively; Coef., coefficient; OR, odds ratio.

diffusion and cross-regional relocation diffusion, demonstrating significant neighborhood and demonstration effects. There is an obvious difference in the timing of policy adoption between sub-provincial cities or provincial capitals and ordinary prefecture-level cities, suggesting that policy diffusion exhibits the "hierarchical pattern" from high to low according to administrative level. However, the gradient difference between eastern, central, and western prefecture-level cities is not apparent. From 2019 to 2020, the scope of policy diffusion is significantly reduced. The prefecture-level cities that have adopted the policy are relatively dispersed in terms of spatial distribution.

Kaplan-Meier survival curves for the observed sample are further plotted. The pilot city, geographic location, and administrative level are used as grouping variables. The results are shown in Figure 4. According to Figure 4a, the survival curve of non-pilot cities is notably higher than that of pilot cities. The results of Log-rank test and Breslow test both show $P < 0.000$, indicating that the diffusion of SC policy in pilot cities is significantly faster than that in non-pilot cities. According to Figure 4b, there is no obvious difference presented in the position of survival curves of the eastern, central, and western prefecture-level cities. The results of Log-rank test and Breslow test both show $P > 0.05$, indicating that

the diffusion speed of SC policy does not differ significantly among eastern, central, and western prefecture-level cities. According to Figure 4c, the survival curve of ordinary prefecture-level cities is clearly higher than that of sub-provincial cities and provincial capitals. The results of Log-rank test and Breslow test both show $P < 0.000$, indicating that the diffusion of SC policy in sub-provincial cities and provincial capitals is significantly faster than that in ordinary prefecture-level cities.

4.2 Diffusion mechanisms of SC policy

4.2.1 Baseline regression

Detecting multicollinearity by calculating the variance inflation factor (VIF), the results indicate that the correlation between the explanatory variables is not severe, with an average VIF value of 1.49 and each VIF value less than the threshold of 10. Using STATA 18.0 software, the results of the baseline regression are shown in Table 2. All five models share the same dataset of 7,671 observation units. Robust standard errors clustered at the city level are used to eliminate the effect of potential heteroskedasticity on regression results. The overall fit is good in terms of model statistics.

The estimation results of Model (1) indicate that the coefficient values of *Cen_pre*, *Pro_pre*, and *Peer_pre* are positive, with all significant at the 1% level. In accordance with Model (3) and Model (5), the positive effects of these three variables on policy adoption remain significant at the 1% level after further inclusion of other independent variables. Therefore, Hypotheses 1, 2, 3a are supported. On the one hand, vertical pressures within the multi-tier administrative system significantly drive the diffusion of SC policy. This finding aligns with the works of Zhang and Zhu (2020), Li and Wang (2024), and Kleider and Toubeau (2022), all of which emphasize the critical role of vertical intervention from superior governments in facilitating policy diffusion. Despite possessing a degree of economic or administrative autonomy and certain discretion over local policy-making, subordinate governments remain subject to significant influence from superior governments. Superior governments not only create the mandatory impulse through administrative authority and performance evaluation but also offer positive incentives by allocating fiscal resources, and additionally establish models for learning and emulation through policy pilots and the promotion of best practices. These mechanisms ensure compliance and responsiveness of subordinate governments to policy preferences or administrative orders of superior governments. Further comparison of the coefficients and odds ratios finds that the influence of vertical pressure from the central government is significantly higher than that from the provincial government. This finding highlights the significant hierarchical characteristic of the policy diffusion process, i.e., municipal governments follow a "top-down" logic of hierarchical transmission in policy formulation. Municipal governments frequently struggle to manage double pressures from superior governments due to inherent limitations in both attention spans and fiscal/administrative resources (Zhu and Zhang, 2019). In the case of unitary states, the political structure is characterized by a central and dominant national government, whereas local or regional bodies exercise only those powers delegated to them by the national authority (Stoney et al., 2023). Therefore, they respond to policy signals from provincial governments in a modest way when they receive redundant or even potentially conflicting signals from the central government. On the other hand, horizontal pressures exert a significant positive influence on the diffusion of SC policy. The interaction and competition among local governments constitute the key mechanism driving policy diffusion and policy convergence (Chen et al., 2025; Chen et al., 2026). Driven by the pursuit of jurisdictional development and performance outcomes, such interaction and competition facilitate the dissemination and transfer of policy knowledge, practical experience, and governance models within horizontal intergovernmental networks. Geographical proximity further intensifies these dynamics, as neighboring regions experience more frequent and efficient information flows, share similar socioeconomic conditions, and face heightened competitive pressures (Füglister, 2012; Zhang and Zhu, 2018). In China, neighboring or socioeconomically similar cities are inclined to learn from and emulate each other's policy innovations. For example, Nanjing City issued the Implementing Opinions of the General Office of the Nanjing Municipal Government on Promoting the Construction of Sponge Cities in July 2016, an initiative that was subsequently echoed by Changzhou City in October of the same year, with the issuance of the Implementing Opinions of the Changzhou Municipal Government on Promoting the Construction of Sponge Cities. In addition, although Hypothesis 3b is not supported, some municipal governments would prefer to develop distinctive policy instruments to avoid being categorized as passive followers. For example, Shenzhen City has developed the "SC Intelligent Management Platform" to optimize water management using big data and Internet of Things. Suzhou City has combined SCC with ancient city protection and cultural heritage to form a unique "city-water symbiosis" pattern. This indicates that in the presence of clear policy signals from the central government, champion-style diffusion may well result in a convergence of policy objectives and a divergence of policy instruments (Strebel and Widmer, 2012; Zhu, 2013). Because local innovations have the potential to be adopted as a national pattern through effective communication channels, which is politically rewarding for local officials (Liu and Li, 2016). This also suggests that despite the lack of sufficient autonomy, horizontal pressures can stimulate innovative impulses among Chinese local governments, which contributes to the country's dynamism and diversity.

Based on Model (2), the coefficient values of *Age_MA*, *Year 2_MA*, and *Year 3_MA* are statistically significant at the 1%, 1%, and 10% levels, respectively. Following Model (3), with the addition of other independent variables, the coefficient values of these three variables remain significant at the 10%, 5%, and 1% levels, respectively. In contrast, the variables of *Year 4_MA* and *Year 5_MA* are not statistically significant in either Model (2) or Model (3). Hence, Hypothesis 4a and Hypothesis 5b are supported. Under the performance-based cadre evaluation system, Chinese central government selects subnational leaders through the promotion tournament. The better the performance ranking of jurisdictions, the higher promotion probability of subnational leaders. This strong incentive leads subnational leaders to become rational economic individuals seeking promotion, with strong motivation and pursuit of performance emphasized by the cadre evaluation system (Zeng

and Zhou, 2024). Within the constraints of upper age limits for promotion and limited tenure, the career incentives of local officials vary depending on their age and tenure. On the one hand, a significant positive impact of mayors' age on policy adoption is identified. As an inherent chronometer of political careers, age reflects an official's career stage and promotion prospects. Numerous studies have proved that the ineligible age of promotion for mayor-level officials is typically 54 or 55 years old (Yu et al., 2016; Wu and Zhou, 2018). Under the implicit institutional constraint of age-based promotion ceilings, local officials' promotion expectations and policy preferences exhibit significant heterogeneity across distinct career stages. Accordingly, the age threshold facilitates mayors to implement strategic resource allocation programs-a phenomenon corroborated by the research findings. Specifically, younger mayors possess a strong aspiration for enhancing their promotion prospects. Political promotion incentives may drive them to rush to achieve visible economic growth (Bai et al., 2025; Mitchell and Yin, 2022). Even mayors who do not seek political promotion have the career incentive to pursue short-term economic development to accomplish appraisal goals or at least not be demoted (Tian and Tian, 2021). As mayors grow older, the total economic output of the jurisdiction has increased, and they tend to pursue other innovative policies to showcase their unique transcript and obtain more promotion opportunities. Since SCC is a strategic initiative that is aligned with national priorities and generates positive externalities, mayors inevitably leap at implementing SC policy in pursuit of other performance criteria. On the other hand, the results indicate that mayors exhibit greater initiative in promoting SCC during their early- and mid-tenure, with a marked decline as their tenure advances. Within China's cadre appraisal system, career incentives directly shape the scope and prioritization of specific initiatives undertaken by local officials during their tenure (Shen, 2022; Zhang and Liu, 2025). To preempt exiting the promotion game due to age limitations, the early- and mid-tenure of local officials is widely deemed a strategic window for achieving measurable administrative accomplishments and accumulating capital for career advancement (Kou and Tsai, 2014). Consequently, during this period, mayors are strongly incentivized to pursue policy innovations-even radical ones-to advance local development (Elston and Bevan, 2020). Positioned as a strategic initiative aligned with national priorities, SCC serves to mitigate flood risk and enhance climate resilience (Kazancı et al., 2025). The adoption and implementation of SC policy not only correspond to sustainable development goals but also signal executive efficiency to superior governments. Furthermore, SCC entails coordination across multiple departments and stakeholders, with its benefits accruing progressively over time rather than appearing immediately (Chang et al., 2025). For mayors, launching SCC in their early- or mid-tenure allows the associated benefits to materialize by their late tenure, thereby providing tangible support for performance assessment. In the latter part of their tenure, mayors face mounting pressure to secure promotion. To seize the dwindling opportunity for career advancement, mayors may concentrate resources and efforts on accelerating economic development and neglect SCC. Additionally, the realization of comprehensive benefits from SCC is such a long-term process that its full effects often become apparent only over an extended timeframe (Chang et al., 2025). When SCC is launched in the latter part of a mayor's tenure, its multifaceted benefits rarely materialize fully in time to count toward the incumbent's measurable performance, and may even risk being attributed to the successor's achievements. Consequently, mayors have diminished incentive to promote SCC during the latter part of their tenure. These findings highlight the significant influence of political career cycles on local officials' policy preferences and resource allocation patterns.

As shown in Model (4), the coefficient value of *Age_PS* is statistically significant at the 10% level. Following Model (5), with the addition of other independent variables, the coefficient value of the variable is no longer significant. The variables of *Year 2_PS*, *Year 3_PS*, *Year 4_PS*, and *Year 5_PS* are not statistically significant in either Model (4) or Model (5). The estimation results show that there is no statistically significant relationship between the age or tenure of municipal party secretaries and policy adoption. Despite serving as paramount leaders within prefecture-level city administrations, mayors and municipal party secretaries diverge significantly in their operational portfolios, accountability frameworks, and incentive structures (Zhang and Liu, 2025). Specifically, in accordance with the provisions of national laws and intra-Party regulations, the mayor is mainly in charge of economic management affairs, public service delivery, and the formulation and implementation of socio-economic policies, whereas the municipal party secretary is primarily in charge of party affairs, personnel arrangements, and political duties. As a systematic project that integrates urban planning, risk prevention and control, ecological restoration, and fiscal expenditure, the implementation and advancement of SCC may be intrinsically linked to the fulfillment of the mayor's core administrative responsibilities in urban governance. Consequently, this issue constitutes a critical component of both performance evaluation metrics and administrative accountability mechanisms for mayors. In contrast, since the municipal party secretary's responsibilities center on Party building, cadre management, and overall planning and coordination, they typically possess neither a clear mandate nor a strong incentive to manage specific projects like SCC. Hence, the age and tenure of mayors exert statistically significant effects on the diffusion of SC policy, whereas no comparable association is observed for municipal party secretaries. This finding also aligns with the works of Yang and Gong (2024) as well as Zhao and Luo (2022), which examine the impact of local officials' promotion incentives on environmental governance and people's livelihood improvement. By revealing the disparities between executive leaders and party leaders in China's policy diffusion processes, an intriguing avenue for future research aimed at better understanding China's multi-leader political setting is pointed out. Notably, due to the distinct attributes of different policies, the role of municipal party secretaries in policy diffusion necessitates further investigation via comparative case studies.

With respect to the control variables, the coefficient of *GDP* is significant only in Model (2) and Model (4). The variables of *Drainage*, *Level*, and *Local* are not statistically significant in any of the five Models. This indicates that the level of economic development, drainage capacity, administrative level, and geographic location lack explanatory power for the diffusion of SC policy. The estimation coefficients of both *Days_rs* and *Opinion*

are all positive and statistically significant at the 1% level in five Models. The estimation coefficients of *Infiltration* are all negative and statistically significant at the 1% level in five Models. The estimation coefficients of *Storage* are all negative and statistically significant at the 5%, 10%, 10%, and 5% levels in Models (1), (3), (4), and (5), respectively. The estimation coefficients of *Finance* are all negative and statistically significant at the 5% level in Models (1), (3), and (5), respectively. The estimation coefficients of *Industry* and *Coastal* are all negative and statistically significant at the 5%, 1%, 5%, 1%, and 5% levels in Models (1), (2), (3), (4), and (5), respectively. This suggests that the increase in the number of rainstorm days and public opinion will facilitate the diffusion of SC policy among prefecture-level cities, whereas infiltration capacity, storage capacity, fiscal dependence, industrial structure, and coastal status have an adverse effect on it. The regression results of control variables are largely consistent with the findings of prior studies (Chen and Wang, 2025; Schoenefeld et al., 2022; Zhu and Zhang, 2019). While motivations triggered by institutional pressures and resource constraints are critical for the adoption decision-making of local governments, governance needs are key antecedents as well (Liu et al., 2025). Of these, regional climate as well as hydraulic and hydrological parameters significantly affect the diffusion of SC policy. Frequent rainstorms, poor green coverage rate, and scarce water supply reflect the increased risk of flooding and challenges of sustainable water resource management, thereby driving the perception of policy issues and policy adoption by local governments. The flexibility of municipal governments to adopt the SC policy based on their own hydrological and biophysical conditions reflects a governance paradigm of "water-related adaptation" (Lissner et al., 2024). This indicates a shift by local governments from passively addressing water-related challenges to proactively engaging with urban water and environmental issues, reflecting an overall trend toward greater mobility and initiative within the Chinese environmental governance system. When the themes and objectives of a policy innovation are closely related to the developmental challenges and priorities of the jurisdiction, it is more likely to draw careful consideration and adoption by local governments, as it promises to cultivate widespread public approval and generate favorable political returns. For example, in 2017, Guangzhou City suffered from heavy rainfall on several occasions (in early May, mid-June, and late August), which caused major impacts on city operations and residential life. Following this policy window, Guangzhou City rapidly adopted the SC policy and promoted SCC to enhance its stormwater management capacity. This indicates that "problem-forcing" and "demand-forcing" are increasingly important driving models for local governments to adopt and implement policy innovations. However, the non-significant coefficients of drainage capacity are unexpected. The reasons may be twofold. On the one hand, this may be attributed to the limitations of its measurement. Specifically, the density of drainage pipes, as a quantitative indicator of traditional gray infrastructure, mainly reflects the scale and coverage of urban drainage systems. Whereas SCC puts more emphasis on the synergy between blue/green and traditional gray infrastructure (Guo et al., 2025; Toledo-Gallegos et al., 2022). On the other hand, the impact of this indicator may be attenuated by other statistically significant variables. Furthermore, differing from the results of spatial dynamics, empirical results show that the coefficients of *Level* are not significant. The reason for this may be that the effect of administrative level is attenuated by other statistically significant variables in the model. Additionally, the variables of *GDP* and *Local* were particularly noteworthy. The empirical results show that geographic location is not statistically significant in any of the eight Models. The level of economic development is statistically significant only in Model (2) and Model (4) of the baseline regression but not in the remaining six models. The combination of this result with the spatial diffusion dynamics leads to the finding that there is no significant difference in the diffusion speed of SC policy among eastern, central, and western prefecture-level cities, as well as prefecture-level cities with varying economic development levels. This is notably divergent from the gradient pattern of policy diffusion summarized in existing research on China, i.e., policy innovations spread first from the economically developed eastern region to the economically less developed central region, and then to the economically underdeveloped western region (Liu and Liu, 2020). Indeed, some studies have noted that while the gradient pattern is able to explain the diffusion of economic policies satisfactorily, it does not perform as well for other policies (Wang and Lai, 2013). The findings confirm this view. The essential differences between various types of policies imply that the diffusion of social and environmental policies in China cannot be simply understood through mechanisms such as local economic incentives alone. It also suggests that future research should extend the gradient pattern to better predict the dynamics of policy diffusion.

4.2.2 Robustness test

To further verify the reliability of the estimation results, robustness checks are performed through the following three steps. First, adding explanatory variables. To eliminate the interference of potential omitted variables on the regression results, the population size (taking the logarithm) and the education level of officials are included in the model. Second, altering the regression sample. The sample of sub-provincial cities and provincial capitals is excluded and the regression is re-estimated. Third, including cubic splines of time. To solve the potential time dependence problem, cubic splines of time are included in the empirical model (Baldwin et al., 2019). Given that the age and tenure of municipal party secretaries show no significant effect on the diffusion of SC policy, the robustness checks are confined to Model (3) concerning mayors. The results of robustness checks are shown in Table 3. Based on the results of robustness checks, the estimated coefficients of independent variables and their significance levels are mostly consistent with the baseline regression results, indicating that the previous results are robust.

5 Conclusion

Taking the process of SC policy from pilot exploration to widespread construction as an example, its spatio-temporal diffusion patterns and complex influencing mechanisms are examined. The results show that the diffusion of SC policy follows an S-shaped curve temporally and involves three distinct stages: local diffusion stage (2015), comprehensive

TABLE 3 Results of robustness checks.

Variables	(1)	(2)	(3)
	Coef	Coef	Coef
Cen_pre	2.049*** (0.388)	2.571*** (0.549)	2.009*** (0.388)
Pro_pre	1.529*** (0.217)	1.593*** (0.252)	0.996*** (0.340)
Peer_pre	1.100*** (0.222)	1.148*** (0.240)	0.322 (0.470)
Age_MA	0.051** (0.024)	0.056** (0.022)	0.039* (0.023)
Year 2_MA	0.390** (0.160)	0.394** (0.169)	0.356** (0.163)
Year 3_MA	0.546** (0.217)	0.565** (0.232)	0.548** (0.221)
Year 4_MA	0.228 (0.196)	0.143 (0.208)	0.209 (0.208)
Year 5_MA	0.334 (0.204)	0.315 (0.230)	0.270 (0.216)
Days_rs	0.078*** (0.027)	0.076*** (0.028)	0.071*** (0.027)
Drainage	−0.014 (0.015)	−0.003 (0.015)	−0.011 (0.015)
Infiltration	−0.048*** (0.014)	−0.048*** (0.013)	−0.052*** (0.014)
Storage	−0.005* (0.003)	0.000 (0.001)	−0.005* (0.003)
GDP	0.416 (0.294)	0.486 (0.301)	0.221 (0.310)
Finance	−1.274** (0.503)	−0.354 (0.533)	−1.448*** (0.510)
Industry	−0.020** (0.009)	−0.014 (0.009)	−0.015 (0.010)
Opinion	0.593*** (0.174)	0.648*** (0.217)	0.654*** (0.178)
Coastal	−0.531*** (0.204)	−0.472** (0.215)	−0.524** (0.204)
Level	0.237 (0.385)	—	0.411 (0.333)
Local	0.051 (0.096)	0.009 (0.101)	−0.006 (0.101)
Pop	0.137 (0.301)	—	—
Edu_MA	0.206* (0.122)	—	—
_spline1	—	—	0.155* (0.087)
_spline2	—	—	−0.533 (0.387)
_spline3	—	—	0.986 (0.740)
Constant	−6.806*** (2.205)	−7.686*** (1.946)	−5.652*** (2.109)
Observations	7671	7085	7671
Log likelihood	−1001.486	−891.540	−996.197
Chi-square	256.70***	211.06***	269.50***
Pseudo R^2	0.126	0.130	0.130

Robust standard errors in parentheses are clustered at the prefecture-level city level; *, **, *** denote statistical significance levels at 10%, 5% and 1%, respectively; Coef., coefficient.

diffusion stage (2016–2018), and saturation diffusion stage (2019–2020). Spatially, the diffusion of SC policy primarily occurs from pilot cities to non-pilot cities and from sub-provincial cities or provincial capitals to ordinary prefecture-level cities. Yet, differing from the gradient pattern of policy diffusion, there is no significant difference in the diffusion speed of SC policy among eastern, central, and western prefecture-level cities. Regarding the mechanisms, empirical analysis confirms that bureaucratic accountability and officials' promotion incentives serve as the pivotal factors facilitating the diffusion of SC policy. More precisely, a one-unit increase in vertical pressure from the central government is associated with 7.768 times higher odds of policy adoption by a prefecture-level city. A one-unit increase in vertical pressure from the provincial government is associated with 4.697 times higher odds of policy adoption by a prefecture-level city. A one-unit increase in horizontal pressure from other prefecture-level municipal governments is associated with 3.074 times higher odds of policy adoption by a prefecture-level city. A one-unit increase in the mayor's age is associated with 1.039 times higher odds of policy adoption by a prefecture-level city. Additionally, compared to the first year in office, the odds of policy adoption by

a prefecture-level city are 1.485 and 1.74 times higher in a mayor's second and third year in office, respectively. However, no statistically significant relationship was found between the age and tenure of municipal party secretaries and policy adoption by a prefecture-level city.

The contributions and potential implications are as follows. To begin with, the spatio-temporal dynamics of the diffusion of SC policy are identified. A comparison between the present findings and those of previous studies on other policy innovations reveals that the diffusion pattern of SC policy has both similar and unique characteristics. This provides a foundation for differentiation and comparisons with future disaster risk management policy research. Simultaneously, a more complicated and comprehensive model is developed to explain how bureaucratic accountability and officials' promotion incentives might either affect or intervene in the diffusion of SC policy. This deepens the understanding of how SC policy diffuses within a unitary state and facilitates policymakers in designing effective strategies to accelerate urban climate adaptation and disaster risk reduction. Furthermore, the study responds to the call for more international perspectives on sustainable development goals and climate change. Since China possesses the world's largest urban population and performs well in solving urban water problems, examining the diffusion of Chinese SC policy can provide insights into global climate response and urban resilience enhancement.

Admittedly, there are several limitations. Specifically, the analysis of local officials focuses solely on mayors and municipal party secretaries, overlooking the potential influence of other political elites. Future research could extend the dataset by including members of the Standing Committee of the CPC Municipal Party Committee and heads of key functional departments, thereby offering comprehensive insight into local officials' incentive structures and behavioral patterns. In the meantime, to highlight the major theoretical arguments, the law of the diffusion of SC policy is only explored in a general sense. Further refinement of the differences in the driving mechanisms at different diffusion stages may reveal more complexities. In addition, similar to much of the previous literature, it is assumed that the effects of variables in different dimensions are linearly additive rather than interactive, which may be theoretically and empirically implausible. Future research on policy diffusion, if it explored the interactive relationship between different drivers, could possibly deepen the understanding of policymakers' decision-making processes in the face of limited attention, resources, and capacity, as well as capture new opportunities to further develop policy diffusion theory.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CQ: Writing – original draft, Formal Analysis, Visualization, Data curation, Methodology. SL: Funding acquisition, Writing – review and editing, Conceptualization.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was supported by National Social Science Fund of China (Grant/Award Number: 21BZZ079).

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Alesina, A., Cassidy, T., and Troiano, U. (2019). Old and young politicians. *Economica* 86, 689–727. doi:10.1111/ecca.12287

An, B. Y., Butz, A. M., Cha, M. K., and Mitchell, J. L. (2023). Following neighbors or regional leaders? Unpacking the effect of geographic proximity in local climate policy diffusion. *Policy Sci.* 56, 825–868. doi:10.1007/s11077-023-09499-1

Bai, Z. L., Zhang, P., and Yi, H. T. (2025). Political career incentives and multitasking trade-off: evidence from setting performance targets in Chinese cities. *China Econ. Rev.* 94, 102537. doi:10.1016/j.chieco.2025.102537

Bailey, I., and Karapin, R. (2025). Compensation, horizontal diffusion, and bottom-up pathways: state climate policies in the United States and Australia. *Rev. Policy Res.*, ropr.70049. doi:10.1111/ropr.70049

Baldwin, E., Carley, S., and Nicholson-Crotty, S. (2019). Why do countries emulate each others' policies? A global study of renewable energy policy diffusion. *World Dev.* 120, 29–45. doi:10.1016/j.worlddev.2019.03.012

Berry, F. S., and Berry, W. D. (1990). State lottery adoptions as policy innovations: an event history analysis. *Am. Polit. Sci. Rev.* 84 (2), 395–415. doi:10.2307/1963526

Brown, L. A., and Cox, K. R. (1971). Empirical regularities in the diffusion of innovation. *Ann. Assoc. Am. Geogr.* 61 (3), 551–559. doi:10.1111/j.1467-8306.1971.tb00806.x

Chang, W. C., Liu, G. Y., Chen, Y., Huo, Z. M., Fang, D. L., Agostinho, F., et al. (2025). Assessing inter-industrial ecosystem service flows and economic benefits of sponge city: a comprehensive input-output analysis. *Environ. Impact Assess. Rev.* 114, 107955. doi:10.1016/j.eiar.2025.107955

Chen, X. N., and Wang, Y. H. (2025). How different patterns of policy attention drive policy diffusion: evidence from China's river chief system. *Policy Stud. J.*, 1–14. doi:10.1111/psj.70087

Chen, J. L., Liu, Z. H., Cai, Q. R., Zhang, W. X., and Ma, F. C. (2025). Diffusion of low-carbon policies among cities: a complex network and evolutionary game approach. *J. Clean. Prod.* 536, 147204. doi:10.1016/j.jclepro.2025.147204

Chen, J. L., Wen, J. Y., Deng, Y. F., Chen, M. W., and Ma, F. C. (2026). Measuring policy diffusion intensity: a text-driven analysis of government documents. *Inf. Process. Manage.* 63 (2), 104383. doi:10.1016/j.ipm.2025.104383

Dui, H. Y., Zhang, H. Q., and Wu, S. M. (2025). A IoT-based novel methodology to optimize multidimensional flood resilience of drainage systems for sponge city. *Sust. Cities Soc.* 130, 106523. doi:10.1016/j.scs.2025.106523

Elston, T., and Bevan, G. (2020). New development: scarcity, policy gambles, and 'one-shot bias'-training civil servants to speak truth to power. *Public Money Manage* 40 (8), 615–618. doi:10.1080/09540962.2020.1757241

Füglister, K. (2012). Where does learning take place? The role of intergovernmental cooperation in policy diffusion. *Eur. J. Polit. Res.* 51, 316–349. doi:10.1111/j.1475-6765.2011.02000.x

Gray, V. (1973). Innovation in the states: a diffusion study. *Am. Polit. Sci. Rev.* 67 (4), 1174–1185. doi:10.2307/1956539

Guo, G. (2009). China's local political budget cycles. *Am. J. Polit. Sci.* 53, 621–632. doi:10.1111/j.1540-5907.2009.00390.x

Guo, Y., and Li, S. C. (2025). Multi-level governance of low-carbon tourism in rural China: policy evolution, implementation pathways, and socio-ecological impacts. *Front. Environ. Sci.* 12, 1482713. doi:10.3389/fenvs.2024.1482713

Guo, Z., Zhang, X., Liu, Y., Gong, L., Li, C. J., and Zhang, Y. (2025). Seasonal contributions and efficiency analysis of green-gray-blue coupled infrastructures system for the improvement of water quality in urban Lakes. *J. Environ. Manage.* 382, 125379. doi:10.1016/j.jenvman.2025.125379

Haase, D. (2025). Sponge city in existing housing stock-more of a dream or reality? *Front. Environ. Sci.* 13, 1653240. doi:10.3389/fenvs.2025.1653240

Han, Y., Li, B. G., Zeng, Y. W., and Lili, L. (2025). Assessing the impact of sponge cities on urban eco-efficiency: integration of ArcGIS and econometric analysis. *Environ. Dev. Sustain.* doi:10.1007/s10668-025-06882-1

Heilmann, S. (2008). From local experiments to national policy: the origins of China's distinctive policy process. *China J.* 59, 1–30. doi:10.1086/tcj.59.20066378

Kazancı, G., Gülümser, A. A., and Costa, J. P. (2025). Sponge city concepts in contemporary literature: trends, thematic clusters and challenges for sustainable urban water management. *Urban Water J.*, 1–20. doi:10.1080/1573062X.2025.2571904

Kleider, H., and Toubeau, S. (2022). Public policy in multi-level systems: a new research agenda for the study of regional-level policy. *Reg. Fed. Stud.* 32 (3), 277–305. doi:10.1080/13597566.2021.2018681

Kou, C. W., and Tsai, W. H. (2014). "Sprinting with small steps" towards promotion: solutions for the age dilemma in the CCP cadre appointment system. *China J.* 71, 153–171. doi:10.1086/674558

Kung, J. K. S., and Chen, S. (2011). The tragedy of the nomenklatura: career incentives andpolitical radicalism during China's great leap famine. *Am. Polit. Sci. Rev.* 105 (1), 27–45. doi:10.1017/S0003055410000626

Leguizamon, J. S., and Crowley, G. R. (2016). Term limits, time Horizons and electoral accountability. *Public Choice* 168, 23–42. doi:10.1007/s11127-016-0347-2

Li, M., and Wang, J. (2024). The impact of vertical and horizontal pressures on policy diffusion: evidence from APLS adoption in China. *J. Chin. Gov.* 10 (4), 558–582. doi:10.1080/23812346.2024.2426769

Li, H. B., and Zhou, L. A. (2005). Political turnover and economic performance: the incentive role of personnel control in China. *J. Public Econ.* 89 (9-10), 1743–1762. doi:10.1016/j.jpubeco.2004.06.009

Liang, C. M., Zhang, X., Liu, J., Liu, L. G., and Tao, S. Y. (2023). Determination of the cost-benefit efficient interval for sponge city construction by a multi-objective optimization model. *Front. Environ. Sci.* 10, 1072505. doi:10.3389/fenvs.2022.1072505

Lissner, T. K., Möller, T., Caretta, M. A., and Mukherji, A. (2024). Effectiveness of water-related adaptation decreases with increasing warming. *One Earth* 7 (3), 444–454. doi:10.1016/j.oneear.2024.02.004

Liu, W., and Li, W. Z. (2016). Divergence and convergence in the diffusion of performance management in China. *Public Perform. Manag. Rev.* 39 (3), 630–654. doi:10.1080/15309576.2015.1138060

Liu, J., and Liu, J. T. (2020). A study on the diffusion mechanism of "no more than one visitfor one item reform": an events history analysis for 294 prefecture-level cities in China. *J. Gansu Adm. Inst.* 4, 26–36+125. (in Chinese).

Liu, Q. H., Cui, W. H., Tian, Z., Tang, Y. D., Tillotson, M., and Liu, J. G. (2022). Stormwater management modeling in "sponge city" construction: current state and future directions. *Front. Environ. Sci.* 9, 816093. doi:10.3389/fenvs.2021.816093

Liu, Z. K., Jiang, C. X., Jin, H., and Zhang, W. W. (2025). Digital innovation diffusion of local government under public crisis: an event history analysis based on the city brain. *Cities* 160, 105811. doi:10.1016/j.cities.2025.105811

Lucas, A. (1983). Public policy diffusion research: integrating analytic paradigms. *Sci. Commun.* 4 (3), 379–408. doi:10.1177/107554708300400303

Ma, Y., and Jiang, Y. (2022). Ecosystem-based adaptation to address urbanization and climatechange challenges: the case of China's sponge city initiative. *Clim. Policy.* 23 (2), 268–284. doi:10.1080/14693062.2022.2131503

Ma, L., Liu, W. X., and Yi, H. T. (2025). Performance feedback and policy diffusion: evidence from Chinese city governments subsidizing new energy vehicles. *Public Manag. Rev.*, 1–26. doi:10.1080/14719037.2025.2578798

Meng, M., Dąbrowski, M., Xiong, L., and Stead, D. (2022). Spatial planning in the face of flood risk: between inertia and transition. *Cities* 126, 103702. doi:10.1016/j.cities.2022.103702

MHURD (Ministry of Housing and Urban-Rural Development) (2014). Technical guidelines for sponge city construction: low impact development rainwater system construction (trial). Available online at: https://www.mohurd.gov.cn/gongkai/zc/wjk/art/2014/art_17339_219465.html (Accessed January 23, 2025).

Mitchell, A. M., and Yin, W. W. (2022). Political centralization, career incentives, and local economic growth in Edo Japan. *Explor. Econ. Hist.* 85, 101446. doi:10.1016/j.eeh.2022.101446

Mondal, A., and Garg, R. D. (2025). Global urban flood dynamics and future vulnerability assessment: a comprehensive study of trends, predictions, and mitigation. *Nat. Hazards* 121, 11187–11207. doi:10.1007/s11069-025-07288-y

Montinola, G., Qian, Y. Y., and Weingast, B. R. (1995). Federalism, Chinese style: the political basis for economic success in China. *World Polit.* 48 (1), 50–81. doi:10.1353/wp.1995.0003

Rogers, E. M. (1983). *Diffusion of innovations.* New York: The Free Press.

Sang, Y. F., and Yang, M. Y. (2017). Urban waterlogs control in China: more effective strategies and actions are needed. *Nat. Hazards.* 85, 1291–1294. doi:10.1007/s11069-016-2614-4

Schoenefeld, J. J., Schulze, K., and Bruch, N. (2022). The diffusion of climate change adaptation policy. *Wiley Interdiscip. Rev.-Clim. Chang.* 13 (3), e775. doi:10.1002/wcc.775

Shen, S. V. (2022). *The political regulation wave: a case of how local incentives systematically shape air quality in China.* Cambridge: Cambridge University Press.

Shen, S. V. (2025a). Governing policy experiments in Chinese cities: lessons on effective climate mitigation. *Policy Stud. J.*, 1–21. doi:10.1111/psj.70026

Shen, S. V. (2025b). Political will as a source of policy innovation. *Policy Stud. J.* 53 (1), 185–200. doi:10.1111/psj.12571

Shipan, C. R., and Volden, C. (2006). Bottom-up federalism: the diffusion of antismoking policies from U.S. cities to states. *Am. J. Polit. Sci.* 50 (4), 825–843. doi:10.1111/j.1540-5907.2006.00218.x

Shipan, C. R., and Volden, C. (2008). The mechanisms of policy diffusion. *Am. J. Polit. Sci.* 52 (4), 840–857. doi:10.1111/j.1540-5907.2008.00346.x

Shirk, S. J. (1993). *The political logic of economic reform in China*. Berkeley: University of California Press.

Stoney, C., Asquith, A., Kipper, K., McNeill, J., Martin, J., and Spano, A. (2023). Policy-making, policy-taking, and policy-shaping: local government responses to the COVID-19 pandemic. *Aust. J. Public Adm.* 82, 440–461. doi:10.1111/1467-8500.12585

Strebel, F., and Widmer, T. (2012). Visibility and facticity in policy diffusion: going beyond the prevailing binarity. *Policy Sci.* 45, 385–398. doi:10.1007/s11077-012-9161-y

Tang, Z. Y., Wang, P., Li, Y., Chen, C. H., Lou, Y. H., and Hu, T. A. (2025). Contributions of urbanization and population growth to changes in urban flood exposure in recent decades. *Sust. Cities Soc.* 130, 106592. doi:10.1016/j.scs.2025.106592

Tian, Z. H., and Tian, Y. F. (2021). Political incentives, party congress, and pollution cycle: empirical evidence from China. *Environ. Dev. Econ.* 26 (2), 188–204. doi:10.1017/S1355770X2000025X

Toledo-Gallegos, V. M., My, N. H. D., Tuan, T. H., and Börger, T. (2022). Valuing ecosystem services and disservices of blue/green infrastructure. Evidence from a choice experiment in Vietnam. *Econ. Anal. Policy* 75, 114–128. doi:10.1016/j.eap.2022.04.015

Walker, J. L. (1969). The diffusion of innovations among the American states. *Am. Polit. Sci.Rev.* 63 (3), 880–899. doi:10.2307/1954434

Wang, P. Q., and Lai, X. J. (2013). A study on the model and mechanism of public policy diffusion in China. *J. Peking Univ. Philosophy Soc. Sci.* 50 (6), 14–23. (in Chinese).

Wang, Y., Jiang, Z., and Zhang, L. (2022). Sponge city policy and sustainable city development: the case of shenzhen. *Front. Environ. Sci.* 9, 772490. doi:10.3389/fenvs.2021.772490

Wang, M. R., Bodirsky, B. L., Rijneveld, R., Beier, F., Bak, M. P., Batool, M., et al. (2024). A triple increase in global river basins with water scarcity due to future pollution. *Nat. Commun.* 15, 880. doi:10.1038/s41467-024-44947-3

World Meteorological Organization (2022). Status of mortality and economic losses due to weather. *Climate Water Extremes*. Available online at: https://storymaps.arcgis.com/stories/8df884dbd4e849c89d4b1128fa5dc1d6 (Accessed January 17, 2025).

Wu, M., and Zhou, L. A. (2018). Political incentives and city construction: the visibility of public projects. *Econ. Res. J.* 53 (12), 97–111. (in Chinese).

Yang, J. K., and Gong, X. C. (2024). Promotion incentives and water pollution control in the context of environment tournaments: evidence on the age of officials from a fuzzy regression discontinuity design. *Manag. Decis. Econ.* 45 (4), 2548–2565. doi:10.1002/mde.4145

Yu, J. H., Zhou, L. A., and Zhu, G. Z. (2016). Strategic interaction in political competition: evidence from spatial effects across Chinese cities. *Reg. Sci. Urban Econ.* 57, 23–37. doi:10.1016/j.regsciurbeco.2015.12.003

Zeng, J. N., and Zhou, Q. Y. (2024). Mayors' promotion incentives and subnational-level GDP manipulation. *J. Urban Econ.* 143, 103679. doi:10.1016/j.jue.2024.103679

Zhang, Y. L. (2015). The formation of public-private partnerships in China: an institutional perspective. *J. Public Policy.* 35 (2), 329–354. doi:10.1017/S0143814X15000185

Zhang, X. R., and Liu, Z. (2025). The impact of municipal leadership tenure stability on low-carbon transition of urban economies in China. *Environ. Sci. Policy* 174, 104271. doi:10.1016/j.envsci.2025.104271

Zhang, Y., and Zhu, X. (2018). Multiple mechanisms of policy diffusion in China. *Public Manag. Rev.* 21 (4), 495–514. doi:10.1080/14719037.2018.1497695

Zhang, Y. L., and Zhu, X. F. (2020). The moderating role of top-down supports in horizontal innovation diffusion. *Public Adm. Rev.* 80, 209–221. doi:10.1111/puar.13140

Zhang, M. T., Chen, W. C., Kou, A., and Wu, Y. J. (2023). Promotion incentives, tenure uncertainty, and local government debt risk. *Financ. Res. Lett.* 56, 104136. doi:10.1016/j.frl.2023.104136

Zhang, X. R., Liu, Z., Walker, T. R., Wilson, J., Tao, X. L., Dong, H. J., et al. (2025). Impact of political incentives on urban green development: an analysis of 284 cities in China. *Cities* 161, 105891. doi:10.1016/j.cities.2025.105891

Zhao, Y. H., and Luo, Y. (2022). Swing with wind or remain firm? A study on the centralperformance appraisal and local people's livelihood governance. *J. World Econ.* 45 (10), 185–211. (in Chinese). doi:10.19985/j.cnki.cassjwe.2022.10.001

Zhou, R. J., Li, P. H., and Zhang, M. (2025). Resilience assessment of sponge city and identification of obstacle factor: a case study of wuhu city, China. *Acta geophys.* 73, 5943–5957. doi:10.1007/s11600-025-01685-4

Zhu, X. F. (2013). Mandate *versus* championship: vertical government intervention and diffusion of innovation in public services in authoritarian China. *Public Manag. Rev.* 16 (1), 117–139. doi:10.1080/14719037.2013.798028

Zhu, X. F., and Zhang, Y. L. (2019). Diffusion of marketization innovation with administrative centralization in a multilevel system: evidence from China. *J. Publ. Adm. Res. Theory.* 29 (1), 133–150. doi:10.1093/jopart/muy034

Zou, Y. H., Meng, F. X., Zhong, N., and Zhao, W. X. (2022). The diffusion of the housingpurchase restriction policy in China. *Cities* 120, 103401. doi:10.1016/j.cities.2021.103401