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Does wealthier mean ecology? The Impact of Economic Growth on Blue Infrastructure Expansion

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Abstract

In the context of rapid urbanization and high-quality development, Blue Infrastructure (BI) has transitioned from passive natural remnants to critical spatial carriers supporting urban resilience and livability. However, the relationship between urban economic development and BI remains heavily debated, characterized by the competing mechanisms of spatial encroachment and governance support. Using panel data from 286 prefecture-level cities in China spanning from 2000 to 2022, this study employs a Two-Way Fixed Effects (TWFE) model and a mediation model to empirically investigate the net effect of economic growth on BI and the transmission mechanism of local fiscal expenditure intensity.

The results reveal three main findings. First, economic growth exerts a significant positive overall effect on BI at the national level, indicating that the governance support effect driven by resource accumulation outweighs the pressure of development encroachment. Second, contrary to the assumption of a smooth fiscal bridge, local fiscal capacity exhibits a significant "masking effect" in the transmission pathway. Rapid economic expansion dilutes relative fiscal expenditure intensity, which in turn partially offsets the potential ecological dividends that economic growth could have released. Third, the transformation chain exhibits profound regional heterogeneity: the Eastern region achieves relatively smooth conversion; the Central region presents a typical masking effect during its rapid economic catch-up; whereas the Western and Northeastern regions face a dual blockage where both the direct growth-driven pathway and the fiscal transmission mechanism fail to function.

This study suggests that BI is not an automatic byproduct of economic growth but a conditionally transformed institutional outcome. Bridging the growth-ecology gap essentially requires sustained fiscal intensity, optimized public resource allocation, and targeted spatial governance strategies tailored to specific regional development stages.

1. Introduction

Against the backdrop of rapid urbanization and the pursuit of high-quality development(Jagadisan Sharmila, 2024; McNabb et al., 2024), blue infrastructure (BI) is shifting from a conventional understanding as natural water bodies to a critical spatial framework that supports urban safety, resilience, and livability(Wang et al., 2025). Whether in flood control and drainage, thermal-environment regulation(Bagheri, 2025), waterfront public-space creation(Kumar et al., 2024), or ecological improvement, the faster cities develop, the more strongly they tend to depend on water systems and their integrated functions(Almaaitah et al., 2021). Yet this is precisely where the paradox arises: the expansionary logic that drives urban economic growth is often accompanied by challenges such as the spread of construction land, shoreline hardening, spatial infilling, and ecological compression, placing continuous development pressure on blue spaces that should otherwise be protected and restored(Jayasoriya et al., 2026; Zhang et al., 2024). In other words, urban development does not naturally lead to the expansion of BI. Rather, it may provide a stronger resource base for BI construction,

while also becoming an important force that erodes blue space(Morgan et al., 2026; Depietri, 2022). In the context of rapid urban development, then, is economic growth a supportive condition for BI expansion, or a force of spatial encroachment? This question concerns not only the evolutionary logic of urban ecological space, but also a broader rethinking of urban development models and spatial governance approaches.

The importance of BI lies not merely in its role as a natural landscape element, but in its function as a compound form of urban infrastructure that integrates ecological regulation, risk buffering, public service provision, and climate adaptation(Puppim de Oliveira et al., 2022). As an important component of urban aquatic ecosystems, BI is closely related to stormwater retention, water purification, and thermal-environment improvement(Cheng et al., 2025; Ahmad Nadeem & Hassan Quamrul, 2025); it also profoundly shapes the openness of waterfront public spaces, the livability of residents' living environments, and the resilience of cities in responding to extreme climate events(Gupta & De, 2024). For this reason, BI should not be understood as passive natural remnants left behind during urban expansion, but rather as public ecological infrastructure that requires long-term planning guidance, sustained public investment, and institutional governance support(Frantzeskaki, 2019). Its expansion, restoration, and maintenance are often determined less by natural conditions themselves than by whether a city possesses the governance capacity and policy willingness to convert development gains into spatial ecological supply(Casiano Flores et al., 2021; Thorne et al., 2018). In this sense, changes in BI are not merely the result of natural-pattern evolution(Cousins, 2017), but also the combined outcome of urban development models, resource-allocation logics(Hoover et al., 2021), and spatial-governance orientations.

However, the impact of economic growth on BI may operate through two competing, and even conflicting, pathways. The first is a spatial encroachment effect characterized by development expansion(Xiao et al., 2022). Urban economic growth is typically accompanied by industrial agglomeration, population concentration, land-value appreciation, and accelerated construction activity(Haaland & van den Bosch, 2015), which further drive the expansion of construction land, the hardening of waterfront shorelines(Wei et al., 2024), and the spillover of low-cost development spaces toward ecological margins. In this process, water bodies and adjacent spaces are often among the first to be incorporated into the logic of urban land capitalization and spatial redevelopment(He & Wu, 2009). Existing blue spaces may therefore continue to shrink as a result of infilling, fragmentation, compression, or functional conversion(Song et al., 2025). Put differently, the faster economic growth proceeds, the more likely cities are to erode their blue ecological foundations under the pressures of spatial production and land development(Yang et al., 2023). The second is a supportive effect based on resource accumulation and improved public-investment capacity. Economic growth not only implies higher development intensity; it may also generate stronger fiscal extraction capacity, a more stable public budget base, and a higher level of infrastructure-investment capacity(Toxopeus & Polzin, 2021), thereby providing the necessary financial and governance conditions for river and lake remediation, water-environment restoration, waterfront public-space creation, and BI construction(Kondolf & Pinto, 2017). In this scenario, economic growth may no longer be merely a source of pressure on blue space, but may

instead become an important supportive condition for its expansion and improvement(Seddon et al., 2020). Thus, the relationship between economic growth and BI is not a simple linear process of promotion or inhibition(Jiang et al., 2022). Its overall effect is essentially the net outcome of two jointly operating mechanisms: development encroachment and governance support(Cai et al., 2020). For this reason, whether economic growth functions as a force of spatial encroachment on BI or as a supportive condition that converts governance resources into ecological spatial supply must be identified and tested empirically.

Existing studies have revealed the importance of BI for urban sustainable development from multiple perspectives. First, a large body of research emphasizes the compound value of blue or blue-green infrastructure in stormwater regulation, heat mitigation, ecosystem-service provision, residents' well-being, and urban climate adaptation, and increasingly regards it as important nature-based infrastructure for addressing urban environmental risks and enhancing resilience(Przestrzelska et al., 2024; Haase, 2015; Veerkamp et al., 2021). Second, studies on urban expansion and ecological-space change show that rapid urbanization is often accompanied by the occupation, compression, and functional disturbance of water bodies, wetlands, and other spaces. Blue spaces are not automatically preserved as cities develop; instead, they are often among the first to come under pressure in processes of land development and spatial reproduction. Taking large Chinese cities as an example, some research finds that between 1990 and 2018, the area of natural water bodies in sampled cities declined by 20.6% overall as a result of urban expansion, indicating the significant erosive impact of urban growth on water-space systems(Xiao et al., 2022). Third, studies on economic growth and fiscal capacity generally point out that local fiscal capacity is directly related to the scale and quality of public investment and infrastructure provision, and that whether local governments can generate stable own-source revenue and financing capacity is an important prerequisite for long-term public construction. The OECD further notes that local governments are key actors in public investment, accounting on average for nearly 60% of public investment across member countries(Camila Vammalle IndreBambalaite, 2021). Nevertheless, although these three strands of literature respectively discuss the functional value of BI, the compression of ecological space caused by urban expansion, and the supportive role of fiscal capacity in public investment, an integrated analytical framework linking them remains insufficient(Ferreira et al., 2024; Allain-Dupré Dorothée, 2011; Valente de Macedo et al., 2021). Existing studies have more often answered what BI does, what losses urban expansion may cause, or why fiscal capacity matters, but have less frequently examined whether, in the context of rapid urban development, economic growth can be transformed into BI supply through fiscal and other governance mechanisms rather than simply intensifying spatial encroachment. In this sense, the transmission chain among growth, fiscal capacity, and BI still requires more systematic empirical identification and theoretical explanation.

Building on the above discussion, the core concern of this study is not whether urban economic growth itself matters, but how it affects BI and whether this effect can be transformed into spatial ecological supply through governance mechanisms. Specifically, this study seeks to answer two interrelated questions:

RQ1: In the context of rapid urban development, does economic growth function as a supportive condition for BI expansion or as a force of spatial encroachment?

RQ2: Does fiscal expenditure intensity constitute an important governance channel through which economic growth affects BI?

The remainder of this paper is organized as follows. Section 2 introduces the study area, variable selection, and research methods. Section 3 presents the empirical results. Section 4 discusses the regional heterogeneity of the impact of economic growth on BI and the suppression effect of fiscal expenditure intensity. Section 5 summarizes the main conclusions and proposes corresponding policy recommendations.

2. Methodology

2.1 Study Area

This study selects 286 prefecture-level or higher cities in China as the research sample, covering the period from 2000 to 2022. As shown in Fig. 1, the sample cities cover the major population and economic agglomeration areas in mainland China, providing an ideal empirical setting for examining the spatiotemporal relationship among economic growth, local public finance, and BI. The suitability of this study area and period is mainly based on the following two considerations.

First, China's urbanization process provides a highly representative dynamic sample for examining the socio-ecological trade-offs associated with BI. Since 2000, China has experienced rapid industrialization and urban spatial expansion, with the area of urban built-up land increasing exponentially. During this dramatic spatial restructuring, BI, as a core element of the urban hydrological cycle and ecological base, has performed key functions such as flood control and drainage, water purification, public-space provision, and climate-resilience enhancement, while also facing multiple development pressures from urban sprawl, shoreline hardening, and encroachment on water systems. More importantly, within China's particular spatial-governance system, local governments deeply intervene in land development and infrastructure provision. Local fiscal capacity is not only a driving engine of urban construction, but also directly determines the intensity of investment in ecological restoration and public goods. This makes Chinese cities an excellent observational window for exploring whether economic growth constitutes a fiscal supportive condition for BI expansion or an encroachment force that leads to spatial compression.

Second, the pronounced spatial heterogeneity within the study area provides conditions for revealing evolutionary patterns across different stages of development. Based on natural endowments and levels of socioeconomic development, this study divides the sample into four major regions: eastern, central, western, and northeastern China. These four regions exhibit clear gradients in development intensity, fiscal foundations, and spatial-governance characteristics. Eastern coastal cities are economically developed and densely built, facing extremely high pressure from land development, but they also

generally possess greater fiscal surplus capacity and stronger investment capacity for ecological governance. The central region, as a hub linking the east and the west, is in an active phase of industrial transfer and urban expansion, where land-use competition between economic growth and ecological conservation is particularly intense. The western region is vast but ecologically fragile; constrained by geographic conditions and a relatively weak fiscal base, its infrastructure construction costs are high. The northeastern region is constrained by the decline of traditional industry and population outflow, and its urban form and ecological-space evolution differ markedly from those of the rapidly expanding cities in eastern and central China. These multidimensional regional differences enable this study to effectively capture the heterogeneous mechanisms through which economic growth affects BI under different fiscal constraints and development pressures.

2.2 Variable Selection

The core explanatory variable in this study is the level of urban economic development, which mainly reflects changes in the economic strength and development level of cities during the study period. This study measures it using per capita gross domestic product (PGDP). Compared with aggregate GDP, PGDP partly removes the interference of population-scale effects and can more accurately characterize differences in development levels across cities; it is therefore more suitable for identifying the impact of economic development on BI. The relevant data are drawn from the China City Statistical Yearbook and the statistical yearbooks of the sample provinces for 2000–2022. Based on systematic compilation and matching of the original statistical materials, this study constructs a cross-year indicator series of PGDP.

The dependent variable is the level of urban BI, with particular attention to its dimension of spatial supply. Given the difficulty of uniformly measuring BI using functional or quality-based indicators in cross-city, long-period comparative research, this study uses the water surface ratio (WSR) to represent it. WSR refers to the ratio of water-body area to total regional area, and can reflect the relative scale of urban water space and its distribution within the overall urban space. In the specific measurement process, this study extracts water-body area indicators for each city from 2000 to 2022 based on the China Land Cover Dataset (CLCD)(Yang Jie & Huang Xin, 2022), and further calculates the ratio of water-body area to the total administrative area of each city to construct a city-level WSR series. The dataset covers land-cover information in China from 1985 to 2023, has a spatial resolution of 30 m and an overall accuracy of 79.31%, and includes land-cover types such as cropland, forest, shrubland, grassland, water, snow and ice, unused land, impervious surface, and wetland. This study selects the water class as the source of water-body area for calculating WSR. Compared with directly using water-body area, WSR can partly eliminate interference caused by differences in city size and is therefore more appropriate for comparing changes in the spatial supply level of BI across cities.

The mediating variable is fiscal expenditure intensity (GOV). This study focuses on the resource base through which local governments convert gains from economic development into public investment and ecological spatial supply. In specific measurement, GOV is represented by the share of local fiscal expenditure in regional GDP. Compared with simply using the total amount of fiscal revenue or

expenditure, this indicator can, to some extent, reflect the intensity of local government fiscal input relative to the size of the urban economy, and is therefore more suitable for characterizing the transmission role of fiscal capacity between urban development and BI supply(Hao et al., 2018). Because BI construction, river and lake remediation, and water-environment improvement depend heavily on local governments' public investment, stronger fiscal capacity makes a city more likely to possess the resource conditions needed to transform economic growth into ecological spatial supply(Ren et al., 2018; Wu et al., 2020). The relevant data are drawn from the China City Statistical Yearbook and the statistical yearbooks of the sample provinces for 2000–2022.

To minimize estimation bias caused by omitted variables, this study further incorporates control variables from the dimensions of urban development intensity, population agglomeration, economic-structure characteristics, and fiscal-resource base. First, the share of built-up land (LAND) is used to measure urban development intensity. This indicator reflects the expansion of urban construction land and the level of spatial hardening, and increases in development intensity often aggravate the occupation and compression of water space; it is therefore necessary to control for this factor(Lin et al., 2017). Second, population density (PD) is used to measure the degree of population agglomeration. Population concentration not only increases demand for urban construction and pressure on infrastructure, but may also indirectly affect BI supply by intensifying competition for land development. Controlling for population density therefore helps separate the interference caused by population scale and agglomeration effects(Wei et al., 2025). Third, the industrial structure upgrading index (IH) is used to characterize the economic-structure features of cities. Industrial upgrading is usually accompanied by adjustments in development models, resource-allocation methods, and land-use patterns, and may further affect the conditions for urban ecological-space governance and BI construction. Including this variable in the model helps control for structural differences across development stages and industrial transformation pathways(Du et al., 2021). In addition, this study introduces local general public budget revenue (GBRLF) as a control variable for the fiscal-resource base. Compared with the mediating variable GOV, which reflects fiscal expenditure intensity, GBRLF focuses more on local governments' fiscal extraction capacity and discretionary fiscal-resource base(Wu et al., 2021). Because fiscal revenue levels may simultaneously affect urban infrastructure-provision capacity and blue-space governance conditions, including this control helps further reduce the interference of differences in local fiscal resources on the estimation results.

In terms of data preprocessing, this study systematically compiles and matches the raw data for each variable and constructs a panel dataset of 6,647 city-year observations for 2000–2022. City samples with missing values are excluded according to data availability to ensure consistency in sample coverage. At the same time, given the strong skewness of variables such as PGDP, PD, and GBRLF, this study applies natural logarithmic transformation to these variables to reduce the influence of extreme values and alleviate heteroscedasticity, thereby improving the robustness of the model estimates. Details are shown in Table 1.

Table 1
Descriptive Statistics of Key Variables (2000–2022)

Variable	Definition	Mean	SD	Min	Max	Obs
WSR	Water Surface Ratio	0.03	0.06	0.00	1.37	6647.00
PGDP	Per Capita Gross Domestic Product (yuan)	38196.76	33478.81	1382.00	256908.00	6647.00
ln_PGDP	Log of Per Capita GDP	10.15	0.95	7.23	12.46	6647.00
GOV	Fiscal expenditure intensity (Fiscal Expenditure / GDP)	0.17	0.12	0.02	1.66	6647.00
PD	Population Density (persons/km²)	422.08	337.27	1.28	3294.94	6647.00
ln_PD	Log of Population Density	5.68	0.99	0.24	8.10	6647.00
LAND	Share of Built-up Land	0.07	0.08	0.00	0.55	6647.00
IH	Industrial Structure Upgrading Index	1.29	0.74	0.17	10.60	6647.00
GBRLF	Local General Public Budget Revenue (yuan)	1592379.00	4350090.00	8700.00	77718002.00	6647.00
ln_GBRLF	Log of Local General Public Budget Revenue	13.19	1.42	9.07	18.17	6647.00

2.3 Research Design and Methods

To explain the impact of urban economic development on BI, this study constructs an analytical framework (Fig. 2). The framework indicates that urban economic development may affect BI through two competing pathways. On the one hand, economic growth is often accompanied by the expansion of construction activities, an increase in land-development intensity, and intensified spatial hardening, thereby exerting pressure on water space and producing a spatial encroachment effect. On the other hand, economic growth may also strengthen local governments' resource-supply capacity and public-investment base, providing support for the construction, restoration, and governance of BI and thereby generating a governance-support effect. In this process, the role of government serves as an important

mediating link between economic growth and BI supply. Whether development gains can be transformed into spatial-governance practices through fiscal expenditure, planning regulation, and governance action directly affects the direction of change in BI. Accordingly, following the logic of overall-effect identification and mechanism-pathway testing, this study first employs a two-way fixed effects (TWFE) model to identify the overall impact of urban economic development on BI, and then further examines whether fiscal capacity plays an important transmission role in this relationship.

For overall-effect identification, the relationship between urban economic development and BI may be affected by both city-specific characteristics and macro-level time factors. This study therefore uses a TWFE model for estimation(Sun & Huang, 2020). This approach effectively controls for time-invariant urban heterogeneity as well as policy shocks, macro-environmental changes, and time trends commonly experienced in different periods, thereby allowing a more accurate identification of the net effect of urban economic development on BI. The baseline model is specified as follows:

$$Y_{it} = \alpha + \beta X_{it} + CV + u_i + \lambda_t + \epsilon_{it} \# (1)$$

where:

Y is the dependent variable: water surface ratio in city i at time t;

X is the core explanatory variable: per capita GDP;

CV denotes a vector of control variables capturing city-level characteristics;

u_i represents city fixed effects;

λ_t represents year fixed effects;

α is the constant term;

ϵ is the idiosyncratic error term.

After identifying the overall effect, this study further examines whether fiscal capacity plays a governance-conversion role in the process through which urban economic development affects BI. According to the analytical framework shown in Fig. 2, if economic growth not only generates development pressure but also supports BI supply by enhancing local governments' fiscal expenditure capacity, then fiscal capacity should constitute an important transmission mechanism linking economic development and BI. Accordingly, this study further constructs a mediation model to examine the pathway through which fiscal capacity operates in the relationship between the two. The empirical strategy follows the classic path-analysis framework proposed by Baron & Kenny (1986), with the specific model specified as follows:

$$M_{it} = \alpha + \beta X_{it} + CV + u_i + \lambda_t + \epsilon_{it} \# \ (2)$$

$$Y = \alpha + c' X + bM + CV + u_i + \lambda_t + \epsilon_{it} \# (3)$$

where:

M is the mediating variable.

3. Empirical Results

3.1 Spatiotemporal Characteristics of Core Variables

Figure 3 presents the spatiotemporal distribution characteristics of the three core variables from 2000 to 2022. In terms of the spatial pattern of BI, WSR exhibits a relatively pronounced regional imbalance. Cities with higher values are mainly concentrated in the eastern coastal region, the middle and lower reaches of the Yangtze River, and areas with dense water networks and lake systems, while the western region, especially the northwestern inland areas, generally has lower values. This indicates that the spatial supply of BI is first and foremost strongly shaped by the natural water-system pattern and geographic background conditions. In terms of temporal evolution, WSR remained relatively stable overall from 2000 to 2022 and did not exhibit the continuous and significant upward trend observed in economic variables. Regionally, the eastern and central regions show a wider distribution range of WSR and larger inter-city differences; the western region has generally lower values and limited variation; and the northeastern region is generally situated between the central and western regions.

By contrast, the level of urban economic development exhibits a clearer and more continuous growth trajectory. Figure 3(b) shows that economic development displays an evident spatial pattern of higher levels in the east and lower levels in the west. High-value cities are mainly concentrated in the eastern coastal region, major urban agglomerations, and selected regional central cities, whereas ordinary cities in the central and western regions generally show lower levels. In terms of temporal change, the economic levels of all four major regions increased significantly during the study period, reflecting the overall continuous improvement of urban economic development in China over the sample period. Nevertheless, the regional development gradient did not disappear. The eastern region consistently maintained a higher development level; although the central and western regions showed a clear catching-up trend, they remained below the eastern region overall; and the northeastern region exhibited some growth but with relatively more pronounced differentiation among cities.

The spatiotemporal pattern of fiscal capacity further reveals a distribution that differs from that of economic development. Figure 3(c) shows that high GOV values are not clearly concentrated in the economically most developed eastern coastal region, but are more prominent in the western region and some border areas. This implies that fiscal capacity is not a simple mapping of urban economic development level; rather, it more closely reflects differences in the intensity of local fiscal expenditure relative to economic scale. In terms of temporal evolution, GOV generally shows an upward trend across all four regions, but its volatility and dispersion are much greater than those of economic development,

especially in the western and northeastern regions, where high-value and low-value cities coexist more prominently.

Overall, during the study period, the level of urban economic development continued to rise nationwide, but BI did not exhibit a synchronous and significant expansion trend. Meanwhile, although fiscal capacity improved overall, its spatial pattern did not fully align with the level of economic development. This preliminary evidence suggests that economic development may exert pressure on blue space through development expansion, while also supporting BI supply through governance conditions such as fiscal expenditure. These spatiotemporal characteristics provide the necessary empirical background for the subsequent identification of the overall effect of urban economic development on BI and the fiscal mediation mechanism.

3.2 Baseline Regression Results

The spatiotemporal patterns described above suggest that more complex statistical relationships may exist among the core variables, providing a practical basis for further econometric identification. Before formal model estimation, this study first tests the relationships among variables and the model specification. The correlation analysis indicates that WSR, GOV, and the control variables are generally significantly associated with ln_PGDP (see SI Table 1), but the simple correlations between the core variables and ln_PGDP are limited, requiring multivariate regression to further control for potential confounders. Meanwhile, the multicollinearity test shows that the variance inflation factors (VIFs) of all explanatory variables are below 5, indicating no severe multicollinearity overall (see SI Table 2). In addition, the model-specification tests provide clear support for the fixed-effects framework (see SI Table 3).

After completing the pre-estimation tests, this study uses a TWFE model to identify the overall impact of urban economic development on BI, as shown in Table 2. Overall, at the national-sample level, the regression coefficient of urban economic development is 0.025 and is significantly positive at the 1% level. This indicates a significant positive association between urban economic development and the increase in WSR; that is, economic growth does not, on the whole, operate as a net encroachment force on BI, but is closer to a supportive condition. This finding is consistent with the empirical evidence of Chen and Wang (2013)(Chen & Wang, 2013). It implies that, when the two mechanisms of development encroachment and governance support coexist, the resource accumulation and governance-support effects generated by economic growth may, in aggregate, outweigh its pressure on blue space.

Further regional subgroup results indicate that this positive effect has clear spatial heterogeneity. In the eastern region, the regression coefficient of ln_PGDP is 0.0384 and is significantly positive at the 1% level. In the central region, the coefficient is 0.0387 and is significantly positive at the 5% level; both coefficients are higher than that of the national sample. By contrast, the coefficient in the western region is 0.0167, which is positive but is not statistically significant; the coefficient in the northeastern region is close to zero and is also insignificant. These results indicate that the promotional effect of economic

growth on BI is mainly concentrated in the eastern and central regions, while no stable statistical association has yet formed in the western and northeastern regions. This suggests that the direction and intensity of the impact of economic growth on BI expansion are strongly shaped by regional conditions.

This pronounced regional heterogeneity indicates that BI, as a public good with both ecological and social value, depends for its supply expansion not only on the scale of the economy, but also on regional development stages and resource endowments. Benefiting from stronger economic foundations, the eastern and central regions may more effectively translate economic growth into improved local fiscal capacity and governance effectiveness, thereby providing solid support for the expansion of blue space. By contrast, the western and northeastern regions may be constrained by traditional development models or transition pressures, such that limited growth dividends are often prioritized for conventional infrastructure or for addressing historical deficits, making it difficult for economic growth to be smoothly converted into BI improvement. Thus, economic growth is not a sufficient condition for blue-space expansion. Its translation into ecological supply requires specific institutional channels, which provides a clear empirical clue for the subsequent discussion of the bridging role played by fiscal capacity.

Table 2
The Impact of Economic Factors on WSR

Variable	**(1)All Cities**	**(2)East**	**(3)Central**	**(4)West**	**(5)Northeast**
ln_PGDP	0.025***	0.0384***	0.0387**	0.0167	-0.0000
	(0.007)	(0.0119)	(0.0163)	(0.0147)	(0.0011)
LAND	0.250**	0.1729	0.5829***	0.1975**	-0.1898*
	(0.106)	(0.1322)	(0.1941)	(0.0980)	(0.1014)
IH	-0.003**	-0.0139***	0.0038	-0.0010	-0.0008*
	(0.001)	(0.0029)	(0.0024)	(0.0007)	(0.0005)
ln_PD	0.027**	0.0402	0.0547*	0.0276	0.0087
	(0.012)	(0.0277)	(0.0283)	(0.0188)	(0.0057)
ln_GBRLF	-0.013***	-0.0142***	-0.0194***	-0.0061	0.0003
	(0.004)	(0.0055)	(0.0067)	(0.0053)	(0.0008)
Observations	6647	1984	1835	2046	782
R^2	0.940	0.968	0.958	0.915	0.984
Adjusted R^2	0.937	0.966	0.956	0.910	0.983

The robustness-test results are shown in SI Table 4. Considering potential time lags in spatial ecological supply, this study replaces the core explanatory variable with the one-period lag of the logarithm of PGDP

(L.ln_PGDP). The coefficient of L.ln_PGDP is 0.0249 and remains highly significant at the 1% level. Meanwhile, under strict controls for both city and year fixed effects, the model maintains a reasonable level of fit (within R-squared = 0.190), confirming that the baseline conclusion is strongly robust to temporal adjustments.

3.3 Mediation Model Results

After establishing the overall promotional effect of economic growth on BI, this section further examines the mediating role of local fiscal expenditure intensity in the growth-ecology transformation chain (see Table 3). Unexpectedly and importantly, fiscal capacity does not exhibit a conventional positive mediating effect; instead, it presents a significant suppression effect.

Specifically, in the national sample, the expansion of the overall economy significantly reduces relative fiscal expenditure intensity, while fiscal expenditure intensity has a significant positive impact on BI. This means that, as the size of the economy expands rapidly, the relative scale of local public fiscal expenditure lags behind or becomes diluted, thereby producing a negative indirect effect on the expansion of blue space. In fact, the comparison between Models (1) and (3) shows that when fiscal expenditure intensity is excluded and then controlled for, the direct positive effect of economic growth on BI increases from 0.025 to 0.029. Put simply, although the economic pie becomes larger, the share allocated to ecological infrastructure does not increase proportionally. This delay in allocation, in effect, acts as a drag and offsets part of the larger ecological benefit that economic growth could otherwise have generated.

The cross-regional mediation models further reveal pronounced spatial differentiation in the economic-fiscal-ecological transformation chain. In the eastern and central regions, fiscal capacity is significantly and positively associated with ecological supply. This indicates that in regions with relatively mature spatial-governance foundations, abundant public resources can be effectively allocated to the construction, management, and maintenance of BI. However, the two regions differ in the first half of the pathway. In the eastern region, economic growth does not significantly dilute fiscal expenditure intensity, allowing growth dividends to be translated into ecological supply relatively smoothly. In the central region, which is undergoing rapid industrialization, economic expansion significantly dilutes fiscal expenditure intensity, producing a suppression effect consistent with that of the national sample. This suggests that, during the process of economic catch-up in the central region, the evolution of the public-expenditure structure may not yet have fully adapted to the expansion of economic scale.

By contrast, the western and northeastern regions display markedly different mechanism characteristics. In these two regions, economic growth not only fails to directly promote BI expansion, but also produces a more severe dilution effect on fiscal expenditure intensity. More importantly, the pathway through which fiscal capacity is converted into BI does not show statistical significance. This dual blockage reflects an objective reality: in regions facing structural transition pressures or limited fiscal endowments, newly generated economic gains are often preferentially allocated to basic infrastructure provision or to maintaining the basic economic fundamentals. This not only leads to a decline in relative

fiscal expenditure intensity, but also makes it difficult for already limited public resources to be directed toward BI as an ecological public good.

In sum, the mediation-effect results verify a key mechanism: the transformation of economic growth into BI expansion is not automatic, but is highly dependent on the effectiveness of local governments' public-resource allocation. The relative dilution of fiscal expenditure intensity constitutes a conversion bottleneck that constrains the release of ecological dividends, and this effect differs sharply across regions at different stages of development. This mechanism provides empirical evidence for understanding imbalances in regional ecological supply and lays the foundation for the subsequent discussion of how institutional design can help bridge the growth-ecology gap.

Table 3
The the Mediating Results

	VARIABLES	(1) WSR	(2) GOV	(3) WSR
(1)All Cities	ln_PGDP	0.025***	-0.062***	0.029***
		(0.072)	(0.206)	(0.076)
	GOV			0.069***
				(0.076)
	LAND	0.250**	-0.508**	0.285***
		(0.106)	(0.242)	(0.098)
	IH	-0.003**	0.007**	-0.003***
		(0.001)	(0.003)	(0.001)
	LAND	0.250**	-0.508**	0.285***
		(0.106)	(0.242)	(0.098)
	IH	-0.003**	0.007**	-0.003***
		(0.001)	(0.003)	(0.001)
	Constant	-0.209***	0.665***	-0.254***
		(0.072)	(0.206)	(0.076)
	Observations	6647	6647	6647
	R-squared	0.940	0.877	0.942
(2)East	ln_PGDP	0.038***	-0.018	0.042***
		(0.190)	(0.218)	(0.154)
	GOV			0.178***
				(0.154)
	LAND	0.173	-0.329**	0.231*
		(0.132)	(0.159)	(0.121)
	IH	-0.014***	-0.008	-0.012***
		(0.003)	(0.009)	(0.004)
	ln_PD	0.040	0.034	0.034
		(0.028)	(0.032)	(0.022)
	ln_GBRLF	-0.014***	0.033***	-0.020***

		(0.006)	(0.011)	(0.006)
	Constant	-0.396**	-0.215	-0.358**
		(0.190)	(0.218)	(0.154)
	Observations	1984	1984	1984
	R-squared	0.968	0.867	0.972
(3)Central	ln_PGDP	0.039**	-0.061***	0.051***
		(0.172)	(0.219)	(0.146)
	GOV			0.205***
				(0.146)
	LAND	0.583***	-0.297**	0.644***
		(0.194)	(0.138)	(0.196)
	IH	0.004	0.007	0.002
		(0.002)	(0.005)	(0.002)
	ln_PD	0.055*	0.070*	0.040*
		(0.028)	(0.039)	(0.024)
	ln_GBRLF	-0.019***	0.013*	-0.022***
		(0.007)	(0.007)	(0.007)
	Constant	-0.422**	0.061	-0.435***
		(0.172)	(0.219)	(0.146)
	Observations	1835	1835	1835
	R-squared	0.958	0.893	0.963
(4)West	ln_PGDP	0.017	-0.086***	0.019
		(0.145)	(0.328)	(0.158)
	GOV			0.025
		(0.145)	(0.328)	(0.158)
	LAND	0.197**	-1.627***	0.237*
		(0.098)	(0.439)	(0.124)
	IH	-0.001	0.004	-0.001
		(0.001)	(0.004)	(0.001)

	ln_PD	0.028	-0.015	0.028
		(0.019)	(0.069)	(0.019)
	ln_GBRLF	-0.006	0.032*	-0.007
		(0.005)	(0.018)	(0.006)
	Constant	-0.186	0.706**	-0.204
		(0.145)	(0.328)	(0.158)
	Observations	2046	2046	2046
	R-squared	0.915	0.885	0.916
(5)Northeast	ln_PGDP	-0.000	-0.114***	0.001
		(0.026)	(0.555)	(0.030)
	GOV			0.007
				(0.030)
	LAND	-0.190*	-3.162***	-0.166
		(0.101)	(0.797)	(0.104)
	IH	-0.001*	0.001	-0.001*
		(0.000)	(0.006)	(0.001)
	ln_PD	0.009	-0.418***	0.012*
		(0.006)	(0.109)	(0.006)
	ln_GBRLF	0.000	0.071***	-0.000
		(0.001)	(0.019)	(0.001)
	Constant	-0.036	2.542***	-0.055*
		(0.026)	(0.555)	(0.030)
	Observations	782	782	782
	R-squared	0.984	0.876	0.985

4. Discussion

This study re-examines the relationship between economic growth and BI expansion. For a long time, traditional urban-development theories, such as the Environmental Kuznets Curve hypothesis, have often implicitly assumed that as the aggregate economy expands and wealth accumulates, ecological improvement will follow, or at least gradually acquire a stronger material foundation. However, the

empirical results of this study show that BI is not a natural spillover outcome of economic growth, but rather an institutional product that can be realized only through processes of public-resource allocation and spatial governance. In other words, economic growth can provide a potential resource base for BI, but whether this potential is truly converted into blue-space supply depends not on growth itself, but on whether growth gains can be effectively embedded in fiscal expenditure and spatial-governance processes. In this sense, what this study identifies is not a simple relationship in which growth inevitably encroaches on ecology or growth automatically improves ecology, but a conditional transformation process characterized by significant regional differences and governance constraints.

First, the significant positive effect of economic growth on BI in the national sample indicates that it is insufficient to understand urban development simply as a process of compressing blue space. At least in the BI dimension examined in this study, economic expansion does not necessarily come at the absolute cost of continuously reducing water space. One possible explanation is that as economic development rises, cities' demand for flood control and drainage, water-environment governance, waterfront-space optimization, and livability improvement also increases, and BI gradually shifts from a passively retained natural element to an actively shaped public ecological space. Thus, economic growth brings not only development pressure, but may also be accompanied by enhanced public-construction capacity, upgraded environmental-governance demand, and stronger demand for spatial-quality improvement. The findings of this study therefore suggest that, in understanding the relationship between economic growth and ecological space, we should not remain solely within the logic of development expansion and ecological compression, but should also recognize that the growth process itself may generate genuine demand and governance momentum for BI.

This overall positive effect is not universal, but is instead characterized by significant regional differentiation. The empirical results show that economic growth is not a sufficient condition for BI expansion; rather, it functions more like a potential supportive condition. Only when growth is combined with certain spatial-governance capacities, resource-allocation modes, and development-stage characteristics can this potential be converted into actual ecological supply. For the eastern region, a stronger economic base, a more mature urban-governance system, and more stable public-investment conditions may make it easier for additional development gains to enter the processes of BI construction, restoration, and maintenance. The significant positive result in the central region indicates that, against the backdrop of rapid catch-up and ongoing spatial restructuring, economic growth is no longer merely a source of development pressure, but has also begun to constitute an important supportive force for BI improvement. This means that ecological supply in the central region is no longer entirely detached from the development process, but has, to some extent, begun to be embedded in regional development and urban construction.

By contrast, the insignificant results in the western and northeastern regions indicate that the transformation chain between growth and BI has not yet been stably formed in these areas. The key point is not to simply attribute this to a lack of ecological awareness. Rather, it more likely means that under different development stages, spatial conditions, and governance pressures, economic growth

prioritizes different problems. In the western region, geographic conditions are complex and cities are relatively dispersed; the relationships among the natural water-system base, ecological constraints, and development demand are often more complicated, and economic growth may not be stably converted into spatial ecological supply. In the northeastern region, industrial transition, population change, and the inertia of existing spatial structures may jointly weaken the linkage between growth and BI. Thus, the formation logic of BI is highly place-specific. It is affected not only by the level of economic growth, but is also deeply embedded in regional development stages, spatial-structure conditions, and governance capacity. The regional heterogeneity results of this study therefore revise the view that attempts to explain ecological-supply changes in all regions through a single growth logic.

If the above findings revise the assumption that growth inevitably encroaches upon ecological space, the test of the fiscal mechanism further revises another assumption: that economic growth will automatically improve ecological supply through enhanced public finance. The mediation results of this study do not support this view. Instead, in the national sample and the central region, the fiscal variable presents a clear suppression effect: economic growth generally promotes BI expansion, but at the same time, economic expansion significantly reduces the relative intensity of fiscal expenditure as a share of GDP, while fiscal expenditure intensity itself has a significant positive impact on BI. In other words, the problem is not that economic growth fails to generate resource expansion, but that as the size of the economy continues to increase, public fiscal expenditure intensity does not rise synchronously, thereby partially offsetting the larger ecological benefits that growth could have released. This can be understood as a lag in the fiscal-ecological response: economic growth has already occurred, but the adjustment in the share of ecology-related public expenditure has not kept pace, constraining the conversion of growth dividends into BI.

The significance of this finding is that it advances the discussion of the relationship between economic growth and ecological governance to the issue of allocation. What determines BI supply is not merely whether economic growth occurs, nor merely whether the total fiscal scale expands, but whether growth gains can enter the public-expenditure system with sufficient proportional weight and priority, and can then be further converted into spatial-governance action. In the results of this study, fiscal expenditure intensity does not appear as a smooth channel that automatically amplifies the effect of growth. Instead, in some samples it becomes a link through which the positive effect is partially suppressed. This suggests that ecological investments such as BI, which are long-term, externality-generating, and public-good oriented, may not increase proportionally with economic growth. On the contrary, during periods of accelerated growth, newly generated resources may be absorbed by other areas with stronger short-term growth effects, rigid expenditure attributes, or higher development priority, thereby reducing the relative expenditure intensity for ecological public goods.

The results for the central region particularly reinforce this judgment. The central region shows both a significant promotional effect of economic growth on BI and a clear fiscal suppression effect. This indicates that the central region does not lack growth dividends; rather, during its rapid economic catch-up, the adjustment of the public-expenditure structure has not fully kept pace with the expansion of

economic scale. The economy is growing and ecological supply is improving, but this improvement could have been stronger. In this sense, the suppression effect identified in this study does not negate the positive role of growth. Instead, it reveals a deeper problem: the resource base created by growth does not automatically translate into the supply of ecological public goods; there remain clear allocation thresholds and governance lags in between.

The eastern region provides an important contrast. In the eastern region, both economic growth and fiscal expenditure intensity show positive associations with BI, but economic growth does not significantly change fiscal expenditure intensity; therefore, a complete suppression chain does not emerge. This means that in regions with more mature governance systems and relatively stable fiscal structures, the relationship between growth gains and ecological supply may be smoother, and fiscal expenditure intensity does not show the significant relative dilution observed in the national sample and the central region. By comparison, the mechanism failure in the western and northeastern regions indicates that in these areas, growth itself has not yet formed a stable promotional effect on BI, and the fiscal pathway has also failed to play an effective conversion role. Thus, the fiscal mechanism is not a uniform explanation that automatically holds across all regions, but rather a conditional mechanism deeply constrained by development stage, economic structure, and governance conditions.

In a broader sense, the findings of this study suggest the need to reconsider the position of BI in urban development. It is neither residual space naturally preserved in the process of urbanization, nor an ecological welfare outcome that automatically spills over from economic growth. Instead, it is closer to an institutional product jointly shaped by development gains, fiscal allocation, and spatial governance. Only when the resources created by economic growth, the priorities embodied in public fiscal expenditure, and concrete actions in spatial governance are effectively connected can BI expand in a stable manner. Accordingly, this study theoretically revises two overly simplified views. The first is the conflict thesis that economic growth inevitably encroaches on ecological space. The second is the transformation thesis that economic growth automatically improves ecological supply through enhanced public finance. By contrast, this study supports a conditional-transformation framework: economic growth provides a potential resource base, while whether BI can expand depends on whether fiscal expenditure intensity is maintained, whether the structure of public expenditure is adjusted in a timely manner, and whether the governance system can effectively embed growth gains into spatial ecological supply. It is in this sense that BI should not be understood as a natural result of growth, but rather as the result of how development gains are governed. This also lays the foundation for the next chapter, which summarizes the conclusions of the study and proposes policy recommendations.

5. Conclusions and Policy Recommendations

5.1 Main Conclusions

Based on panel data from 286 prefecture-level or higher cities in China from 2000 to 2022, this study empirically examines the impact of economic growth on BI, represented by WSR, and its regional

heterogeneity, and further analyzes the mechanism role of fiscal expenditure intensity in the growth-ecology transformation chain. The findings revise the traditional conflict thesis and automatic-transformation thesis, and reveal the resource-allocation and spatial-governance logic underlying the evolution of BI. The main conclusions are as follows.

First, economic growth significantly promotes BI expansion overall, but this effect is highly spatially heterogeneous. The empirical results show that it is inaccurate to equate urban economic development simply with encroachment on blue space. During the sample period, economic expansion did not occur at the absolute and continuous cost of compressing water space; instead, the resource-accumulation and governance-support effects it generated were stronger overall than the development-compression effect. However, this positive transformation depends heavily on regional development stages and governance foundations. The promotional effect is mainly concentrated in the eastern and central regions, where the economic base is stronger and the governance system is more mature. In the northeastern and western regions, which face structural transition pressures or are constrained by complex geographic conditions, economic growth has not yet formed a stable and significant promotional effect on ecological space. This means that economic growth provides a potential resource base rather than a sufficient condition for ecological improvement.

Second, fiscal expenditure capacity does not operate as a traditional positive mediator, but instead presents a suppression effect, that is, an inhibitory mediation mechanism. The results show that the expansion of the aggregate economy directly improves BI, but at the same time significantly reduces the relative intensity of fiscal expenditure as a share of GDP, thereby partially offsetting the larger ecological dividend that could otherwise have been released. This suppression effect is particularly significant in the national sample and in the rapidly catching-up central region. It reveals a pronounced lag in the evolution of the public-expenditure structure: while the economic pie grows larger, the relative expenditure share allocated to ecological and other public-good domains does not increase proportionally. In cross-regional comparison, the eastern region does not show significant dilution because its fiscal structure is relatively stable, with only part of the chain established; in contrast, the western and northeastern regions face the dual dilemma of growth stagnation and fiscal dilution, resulting in a complete mechanism failure.

5.2 Policy Recommendations

The above conclusions indicate that BI expansion is essentially the result of how development gains are effectively governed and allocated. In the process of advancing new-type urbanization and Ecological Civilization construction, bridging the gap between economic dividends and ecological supply requires optimizing spatial-governance and fiscal-allocation mechanisms at the level of institutional design. Accordingly, this study proposes the following policy recommendations.

First, it is urgent to overcome the path dependence of local governments' pro-growth bias and reshape an institutional incentive framework based on natural-capital accounting. The essence of the fiscal suppression effect is that, when facing multiple policy objectives, local governments structurally

underprioritize investment in ecological public goods that are long-term and generate positive externalities. To reverse this tendency, ecosystem services valuation (ESV) or natural-capital accounting should be incorporated into local government performance-evaluation systems. By establishing rigid ecological thresholds, such as WSR baselines and hydrological connectivity requirements, in spatial planning, higher-level governments can create top-down pressure that compels local governments to proactively optimize the structure of public expenditure. This would ensure that fiscal expenditure intensity for ecological governance is not diluted during periods of rapid economic expansion, thereby enabling anticipatory governance of environmental risks.

Second, spatially targeted ecological fiscal transfers and differentiated spatial-control strategies should be implemented. Given the mechanism failure observed in the western and northeastern regions, reliance on endogenous economic growth alone is unlikely to spontaneously drive BI expansion. Top-down spatial intervention and cross-regional coordination are therefore particularly important. Central and provincial governments should substantially increase targeted fiscal transfers to ecologically fragile areas and post-industrial cities, and should establish cross-boundary payments for ecosystem services (PES) mechanisms to bridge the gap between local fiscal capacity and ecological-management needs. Spatial intervention strategies should be tailored to local conditions. In the western region, efforts should focus strictly on protecting the natural water-system base and restoring ecologically degraded areas. In the eastern and central regions, policy should shift toward nature-based solutions (NbS), with emphasis on promoting the deeper integration of blue-green infrastructure and improving the socio-ecological quality of waterfront public spaces.

Finally, diversified financing channels for BI should be expanded to reduce excessive dependence of ecological governance on traditional local public budgets. In the face of unavoidable adjustment pressures in public-expenditure structures during periods of economic expansion, simply requiring an increase in the share of general government budgets faces practical constraints. It is therefore necessary to introduce market-based instruments and public-private partnerships (PPPs). Land value capture (LVC) and other mechanisms for recovering spatial premiums should be widely adopted so that increases in surrounding land value generated by BI improvement can be internalized as funding sources for ecological-facility construction and long-term maintenance. At the same time, municipal green bonds should be encouraged to guide social capital into the integrated governance of urban water-network systems. By building diversified investment-allocation channels, cities can effectively offset the constraints caused by fiscal-expenditure dilution and provide a financially resilient basis for the sustained supply of blue space

Declarations

Author Contribution

S.D. and Z.W. wrote the main manuscript text. P.Y. processed and statistically analyzed the data and prepared the data visualizations. X.M. checked the translation and language accuracy. H.C. reviewed and

revised the manuscript.

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Figures

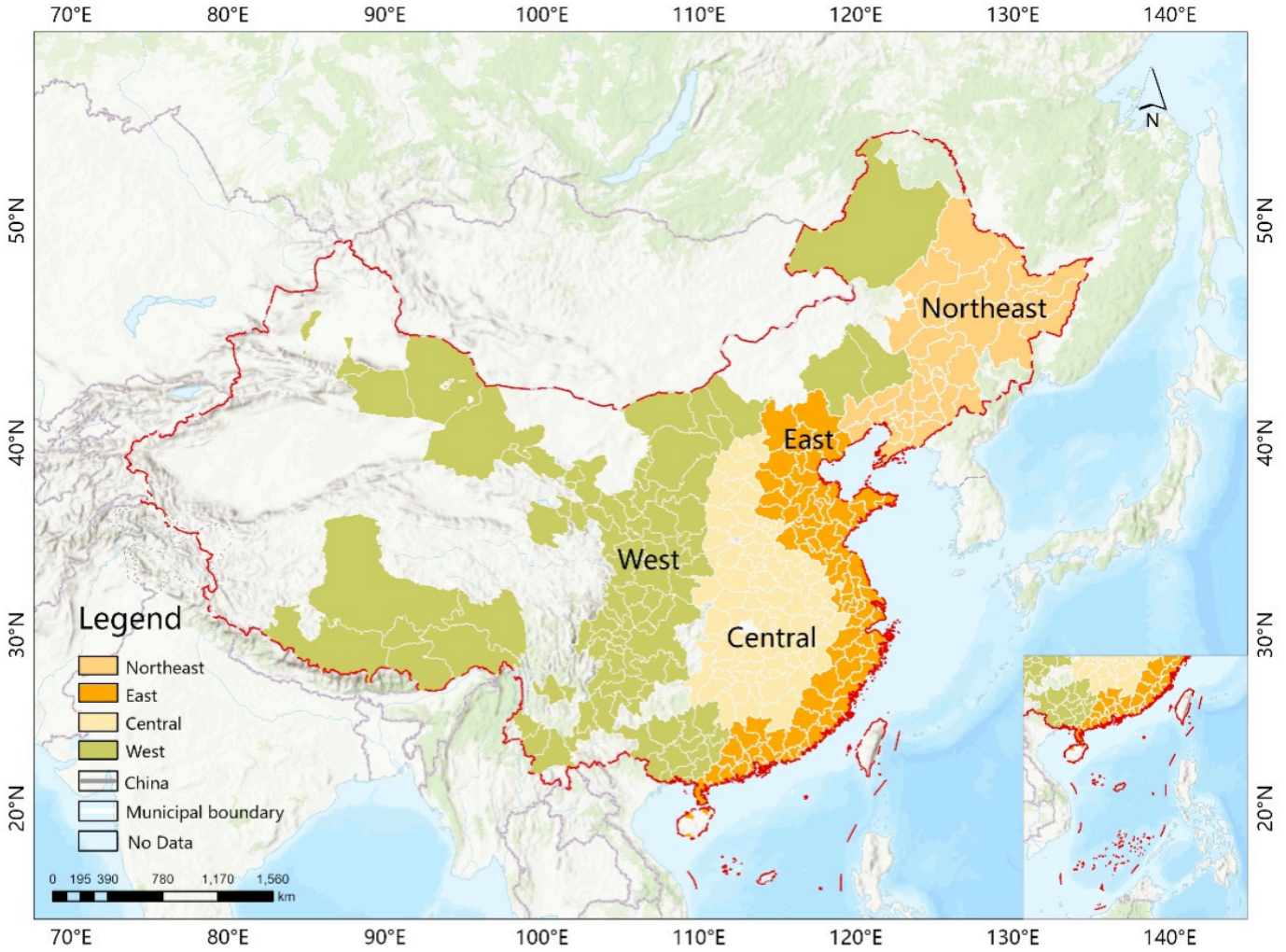


Figure 1

Study area

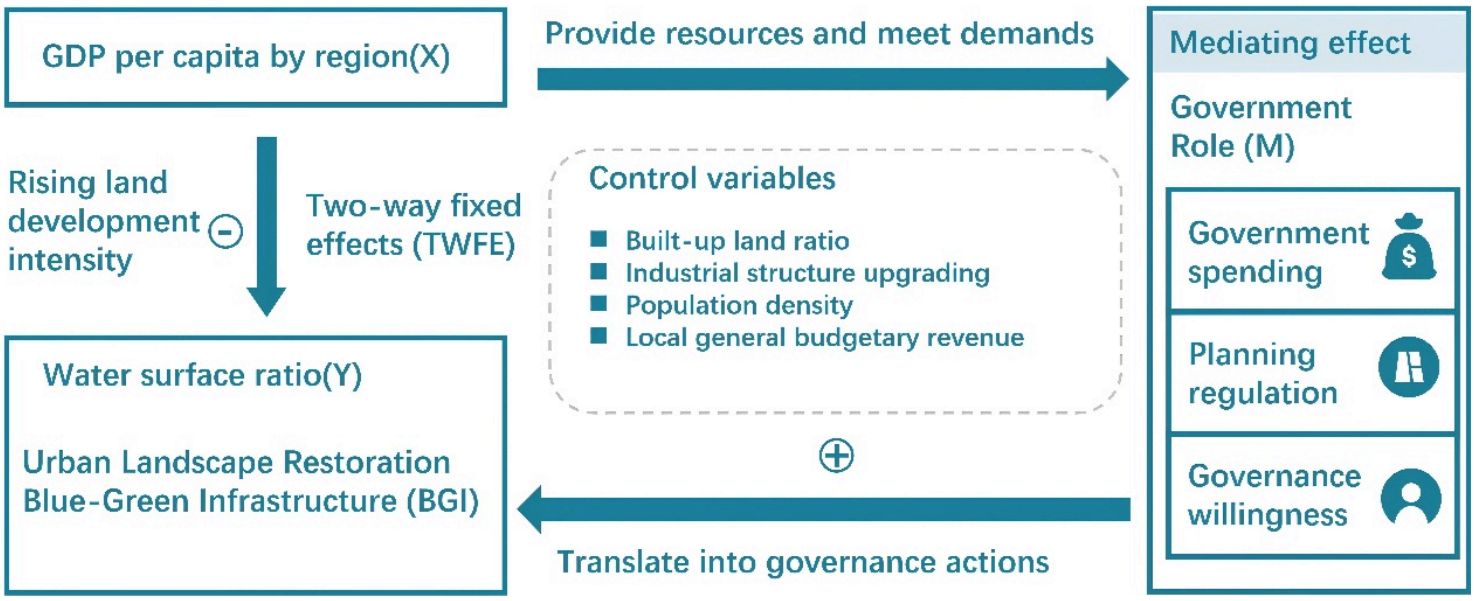


Figure 2

Research framework

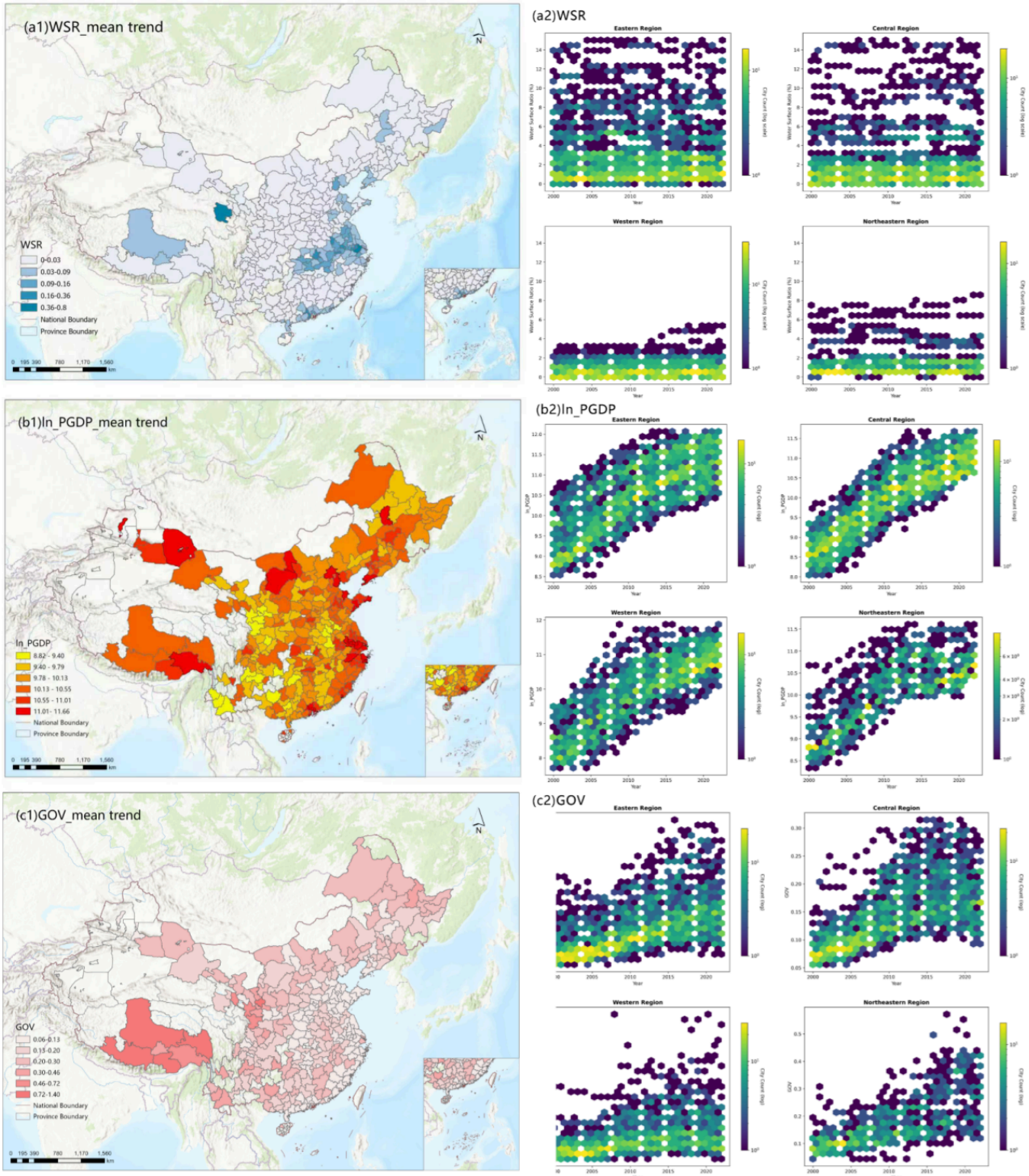


Figure 3

Spatiotemporal characteristics of core variables

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