IOCUS 2026 Conference

The 1st International Online Conference on Urban Sciences

20–22 May 2026 | Online

MDPI

County-Level Urbanization and Its Driving Mechanisms in China: A Spatiotemporal Analysis Using GTWR

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INTRODUCTION & AIM

Urbanization is a fundamental driver of socioeconomic transformation, with distinct trajectories across regions. While Western countries experienced gradual urbanization, China has undergone a rapid and compressed process and has now entered a stage of quality-oriented development. Within China's territorial spatial planning system, counties serve as the key interface linking urban and rural systems, playing a critical role in spatial coordination and balanced development. However, the spatiotemporal patterns and driving mechanisms of county-level urbanization remain insufficiently understood.

This study examines the spatiotemporal evolution of county-level urbanization in China (2010-2020) and identifies its key driving factors using a GTWR model.

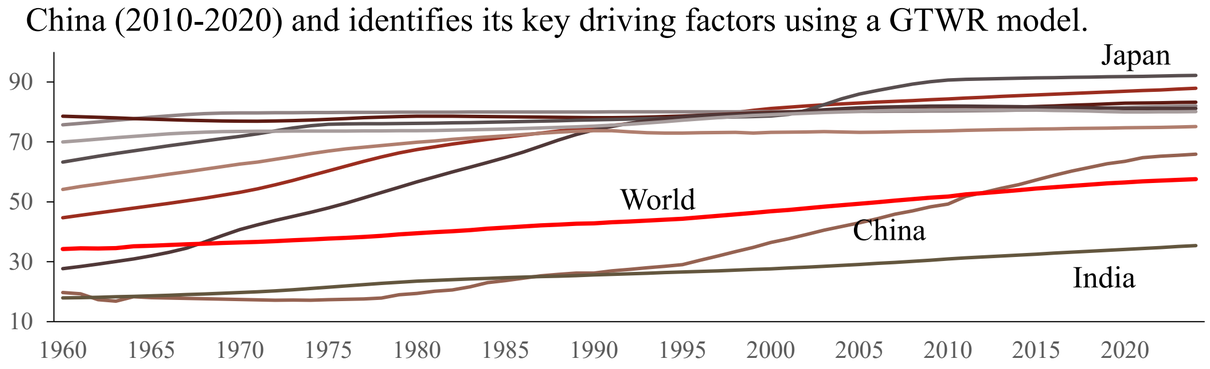

Fig 1. Urbanization curves of major countries, 1960–2024

METHOD

The study analyzes 1,871 county-level units across China (excluding municipal districts). Multi-source data were integrated, including socioeconomic statistics, population census data, and geospatial datasets. A GTWR model was employed to capture both spatial heterogeneity and temporal dynamics in the urbanization process. Compared with OLS and GWR models, GTWR provides improved explanatory power by incorporating time–space interactions. Nine variables were selected across natural environment, infrastructure, population structure, industrial structure, agricultural development, and policy support. Model diagnostics indicate no significant multicollinearity, and GTWR outperforms alternative models ($R^2 = 0.806$).

Table 1. Variables and Descriptions

Dimensions	Variables	Definition	Mean	Std. Dev	Min	Max	VIF
Natural Environment	X1	Average slope	3.42	3.03	0.04	16.57	1.72
Infrastructure	X2	Road density	0.16	0.11	0.00	0.96	1.54
	X3	Education level	8.30	1.08	2.00	11.14	1.98
Population Structure	X4	Young and middle-aged population ratio	0.67	0.05	0.42	0.90	1.62
Industrial Structure	X5	GDP per capita	36583	32200	1314	756182	2.31
	X6	Non-agricultural share	0.78	0.12	0.20	1.00	1.71
Agricultural	X7	Agricultural productivity	1.72	1.42	0.17	10.50	1.84
Development	X8	Agricultural mechanization	40.18	39.68	1.00	300.00	1.41
Policy Support	X9	Fiscal expenditure	9768	11016	434	196718	1.52

Table 2. Comparison of the parameters of each model.

Model	Bandwidth	Residual Squares	R^2	Adj.R^2	AICc
OLS	-	32.360	0.658	0.658	-7136.88
GWR	0.114996	21.3596	0.774305	0.773761	-8554.29
GTWR	0.114996	18.3874	0.80571	0.805242	-9007.92

RESULTS & DISCUSSION

Spatiotemporal Patterns of Urbanization

The average county-level urbanization rate increased from 34.00% (2010) to 47.08% (2020). A clear spatial gradient persists, decreasing from eastern coastal regions to western inland areas. Urbanization growth exhibits significant regional variation. Central provinces demonstrate rapid growth, reflecting a catch-up effect, while developed coastal regions show slower increases due to saturation. Northeast China exhibits relatively weak growth, indicating structural challenges.

Driving Mechanisms

(1) Natural constraints (slope) exhibit strong negative effects in western China, limiting infrastructure expansion and urban development, while flat terrains in Northeast China promote urbanization. (2) Infrastructure and human capital factors (road density and education level) consistently show positive effects, highlighting the role of accessibility and labor quality in facilitating urban growth. (3) Population structure, particularly the proportion of young and middle-aged population, has an increasingly positive influence, reflecting the importance of labor supply in sustaining urbanization. (4) Industrial structure plays a dominant role. The effect of GDP per capita shifts from negative to positive, indicating a transition toward development-driven urbanization, while non-agricultural activities significantly promote urban growth. (5) Agricultural development shows mixed effects. Higher productivity supports rural transformation, whereas mechanization tends to reduce labor demand and suppress local urbanization, except in frontier regions. (6) Policy support has evolved from a negative to a positive influence, suggesting that increasing fiscal investment enhances infrastructure and public services, thereby promoting urbanization.

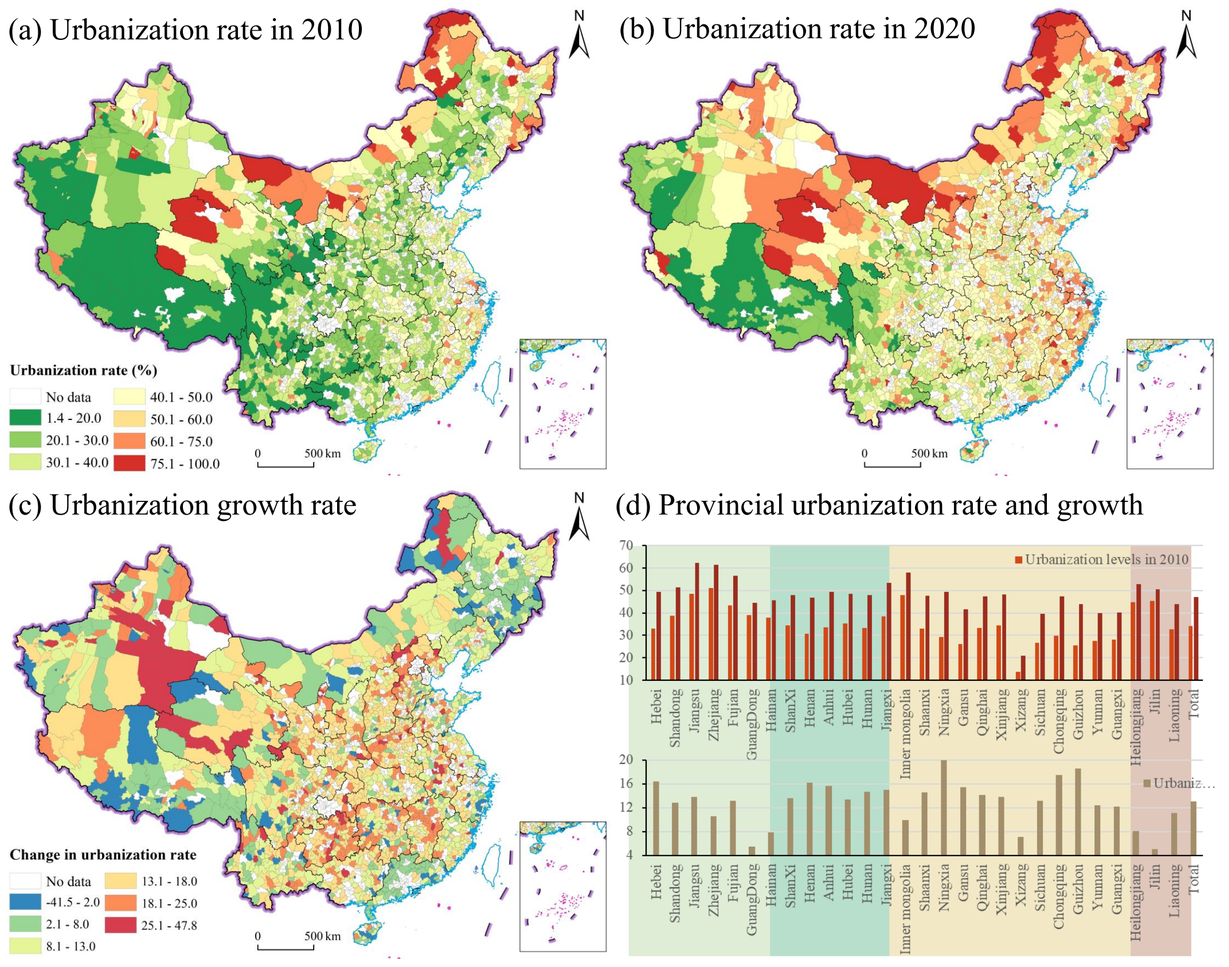

Fig 2. Spatial distribution of county-level urbanization rate and growth

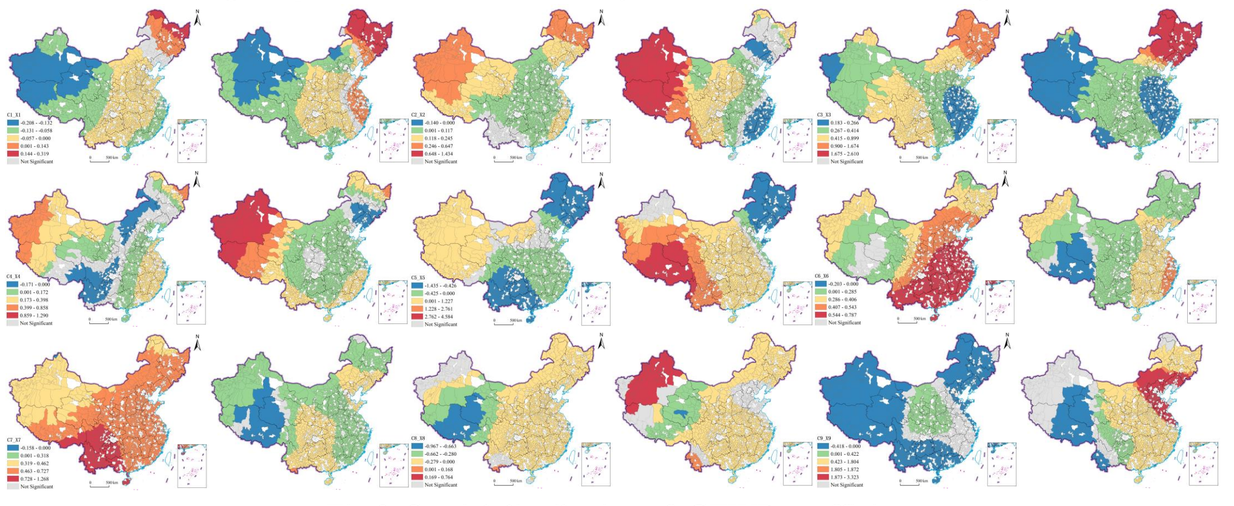

Fig 3. Spatial distribution of GTWR coefficients

CONCLUSION

This study reveals clear spatiotemporal heterogeneity in county-level urbanization across China. While overall urbanization levels have increased substantially, regional disparities persist. Economic restructuring, population dynamics, and infrastructure development are the primary drivers of urbanization, with their effects varying across space and time. Policy intervention has become increasingly important in shaping urbanization outcomes. Counties play a pivotal role as the spatial nexus of urban–rural integration and should be prioritized in future development strategies.

FUTURE WORK / REFERENCES

Future research should incorporate longer time-series data and dynamic policy variables to better capture evolving urbanization processes. Integrating micro-level data and exploring causal mechanisms would further enhance the robustness of the analysis.

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