ORIGINAL RESEARCH ARTICLE

Trends and regional disparities in maternal mortality in China: A nationwide analysis, 2005–2020

DOI: 10.29063/ajrh2026/v30i15.6

Jue Tang[1] *and Fei-Hong Hu*[2]*

General Surgery Department, Affiliated Hospital of Jiangnan University, Wuxi City, PR China[1]; Nursing Department, Affiliated Hospital of Jiangnan University, Wuxi, Jiangsu, PR China[2]

***For Correspondence:** Email: *feihong0101@126.com*; Phone: +008613861782358

Abstract

This study aimed to explore disparities in MMR across China's provincial administrative regions from 2005 to 2020. We undertook spatial autocorrelation analysis to quantify the spatial distribution pattern of MMR and conducted Bayesian spatial modeling to explore factors influencing its spatiotemporal differences. The results showed a significant overall decline in MMR during the study period, with reduced regional inequality in its distribution. Spatial autocorrelation analysis confirmed significant positive spatial clustering (global Moran's I: 0.155–0.367, all P<0.001). Most included variables exerted significant effects on MMR, except the Disease Detection Rate in Women Undergoing Pre-Marital Health Checks. Notably, despite the overall downward trend, persistent geographic disparities existed: MMR was higher in western China and lower in eastern China, with per capita consumer expenditure the most influential factor. This study clarifies the spatiotemporal evolution and key influencing factors of provincial MMR in China, providing insights for targeted interventions to reduce regional disparities. *(Afr J Reprod Health 2026; 30 [15]: 52-65).*

Keywords: Maternal, Mortality, Spatio-temporal, Bayesian spatial modeling, China

Résumé

Cette étude vise à analyser les disparités du taux de mortalité maternelle (TMM) entre les différentes provinces administratives chinoises sur la période 2005 à 2020. Nous avons réalisé une analyse d'autocorrélation spatiale pour caractériser la distribution spatiale du TMM et mis en œuvre une modélisation spatiale bayésienne afin d'identifier les facteurs déterminants ses variations spatio-temporelles. Les résultats révèlent une baisse globale marquée du TMM durant la période étudiée, accompagnée d'une diminution des inégalités territoriales de sa répartition. L'analyse d'autocorrélation spatiale confirme une forte agrégation spatiale positive (indice de Moran global : 0,155 à 0,367, tous p < 0,001). La majorité des variables retenues exercent une influence significative sur le TMM, à l'exception du taux de dépistage des maladies lors des bilans de santé prénuptiaux chez les femmes. Malgré la tendance générale à la baisse, des écarts géographiques persistants subsistent : le TMM reste plus élevé dans l'Ouest de la Chine et plus faible dans l'Est, les dépenses de consommation par habitant constituant le facteur d'influence majeur. Cette étude précise l'évolution spatio-temporelle et les principaux facteurs explicatifs du TMM provincial en Chine, et offre des pistes pour mettre en place des mesures ciblées visant à réduire les disparités régionales. *(Afr J Reprod Health 2026; 30 [15]: 52-65).*

Mots-clés: Mortalité maternelle, Spatio-temporel, Modélisation spatiale bayésienne, Chine

Introduction

The maternal mortality ratio (MMR) serves as a crucial metric for assessing the health status of mothers and children within a given country or geographic area. This study uniformly defined MMR as the number of maternal deaths per 100,000 live births. According to the World Health Organization and the National Vital Statistics Reports published in the United States, maternal mortality is the death of a woman while pregnant or within 42 days after the end of pregnancy, resulting from any cause directly linked to or exacerbated by the pregnancy itself or the management thereof, excluding deaths attributable to unintentional or incidental factors.[1]

Maternal health transcends the realm of merely medical concerns; it is a complex societal challenge intricately intertwined with a myriad of eco-social dynamics, lifestyle decisions, environmental influences, and individual-level determinants.[2] Over the past few decades, the global MMR has seen a significant decline, a trend largely attributed to rapid economic growth and advancements in medical and healthcare practices.[3] However, existing studies on global and national MMR trends primarily focus on overall temporal changes, lacking in-depth spatial analysis of subnational regional disparities and ignoring the spatial heterogeneity of influencing factors. China stands out as a prime example of this encouraging trend. Bolstered by recent years of rapid economic and medical progress, China has made substantial strides in reducing its MMR from 39.0 per 100 000 live births in 2005 to just 9.4 per 100 000 live births in 2020.[4 5] To date, China has not just met but exceeded the mid-term goal set for 2030, which aims to lower the global MMR to 70 per 100 000 live births.[6] This accomplishment not only highlights China's commitment to improving maternal health but also significantly contributes to the global effort to reach this sustainable development goal.

Nonetheless, scrutinizing the MMR on a province-by-province basis reveals significant and enduring regional inequalities, notwithstanding the overall decline.[6-9] Building on the global and national declining trend mentioned above, regional differences in China's MMR have become an increasingly prominent issue that cannot be ignored. For example, in 2020, the MMR in the Tibet Autonomous Region (47.9 per 100 000) exceeded the national average by over 5 times, and was more than 10 times higher than the developed eastern province of Zhejiang (3.9 per 100 000). There exists considerable heterogeneity across different regions in China in terms of levels of medical technology, physical condition of pregnant women, economic factors, and geographic environments.[10-12] This profound heterogeneity across the nation's provinces and localities presents a formidable obstacle for both the central government and local authorities as they endeavor to promote equity in maternal and reproductive health care delivery. These disparities influence the process of childbirth for mothers and the risk of death occurring. At times, the impact of these factors is equally as important as the treatment itself, yet their role is often overlooked.

Spatial epidemiology has been widely applied to study the spatial distribution patterns of diseases,[13 14] thereby providing valuable insights to inform policy development. Examining MMR levels and trends at the subnational level will help identify success stories and areas that may require additional resources to reduce its MMR. With China's expanding efforts to boost public health in partner nations under the Belt and Road Initiative, close examination of its provincial-level regions' performance will prove crucial, particularly for economically disadvantaged areas and countries. The insights gained can guide China's government and health authorities abroad in devising impactful strategies to uplift maternal and infant health standards. This study employs Bayesian spatial modeling—a robust approach that offers distinct advantages over traditional statistical methods, including better handling of spatial autocorrelation, uncertainty quantification, and the ability to integrate spatial and temporal data to identify context-specific influencing factors. The core innovation of this study lies in three aspects: first, it fills the gap of insufficient spatial analysis in existing MMR research by focusing on subnational spatial heterogeneity; second, it combines temporal trend analysis with spatial distribution research to realize comprehensive spatial-temporal characterization of MMR in China; third, it takes China as a typical case to provide actionable insights for global maternal health equity.

Therefore, the core research goal of this study is clearly stated as follows: to explore the disparities in MMR across China's provincial administrative regions from 2005 to 2020 using all available data sources, identify inequalities in MMR among different regions, and uncover the potential risk factors influencing these rates.

Methods

Data collection

The geographic base data used in this paper is derived from the 1:16 million scale China provincial administrative boundary data for 2022 provided by the National Geomatics Center of China [GS (2022)1873], with the provincial units serving as the basic spatial units of analysis.

First, we collected the data on MMR, which includes provincial-level statistics on maternal deaths nationwide from 2005 to 2020. As data on MMR is missing for Taiwan Province and the

Special Administrative Regions of Hong Kong and Macau, the actual study area comprises the remaining 22 provinces, 4 municipalities, and 5 autonomous regions, totaling 31 provincial-level administrative divisions, excluding Hong Kong, Macau, and Taiwan. In addition, we obtained data on medical conditions, diseases, environmental factors, and economic indicators for these provincial-level administrative divisions from the Chinese Health Statistical Yearbook, Chinese Statistical Yearbook, and the Sixth and Seventh National Population Censuses of China. Detailed variables are presented in Table 1.

Ethical approval

The data of this study were derived from public Chinese government documents. This study only conducted a cross-sectional analysis of anonymized data and did not involve personal privacy; therefore, ethical approval was not available.

Data analysis

First, we performed min-max normalization on the raw data to facilitate comparison. As Hainan Province is not directly connected by land to other provinces and municipalities, it was excluded when constructing the neighborhood weights matrix W (spatial adjacency matrix). Moran's I statistic, a classic indicator of global spatial autocorrelation, compares the overall regional mean of an attribute with the attribute value for each spatial unit. This allows us to detect the overall spatial correlation of MMR in China from 2005 to 2020; specifically, it helps determine whether the spatial pattern of national MMR presents a clustered (positive correlation), dispersed (negative correlation), or random distribution. Furthermore, local spatial autocorrelation analysis was undertaken to quantify how the spatial distribution of MMR provinces.

$$Moran's\ I = \frac{K\sum_{k=1}^{K}\sum_{j=1}^{K} w_{kj}(r_k - \bar{r})(r_j - \bar{r})}{\left(\sum_{k=1}^{K}\sum_{j=1}^{K} w_{kj}\right)\sum_{k=1}^{K}(r_k - \bar{r})^2}$$

K is the number of spatial units (provinces, excluding Hainan Province); w_{kj} is the element of the neighborhood weights matrix W (1 if province k and province j are adjacent, 0 otherwise); r_k and r_j are the MMR values of province k and province j, respectively; $\bar{r}$ is the average MMR of all spatial units.

Further analysis of the spatial heterogeneity and internal spatial relationships of MMR conducted using the Getis-Ord Gi* statistic to obtain local Gi* values at the provincial scale. Based on the natural breakpoint method, these were classified into four types: high MMR clustered with other high rates (high-high), high rates clustered near low rates (high-low), low rates clustered near high rates (low-high), and low rates clustered with other low rates (low-low) between provinces and cities.

To investigate the patterns and changes in MMR across different regions over time, we begin by calculating the average risk level across China's 30 provincial-level divisions for each year and Markov Chain Monte Carlo (MCMC) sample. This provides the posterior distribution of these geographic mean values annually. In addition, we quantified the spatial inequality in MMR by the interquartile range (IQR) of mortality risk across the provinces for each year , where a larger IQR indicates greater spatial inequality in MMR across provinces.

We conducted Bayesian spatial modeling utilizing conditional autoregressive (CAR) priors to explore the factors influencing the spatial and temporal differences in maternal mortality. The ordering of all spatial units remained consistent with the neighborhood weights matrix W. Three independent Markov chains was performed to generate MCMC samples. Each chain ran for 17 600 000 samples, with the first 1 600 000 samples discarded as burn-in, and the remaining 16 000 000 samples thinned by 4000 to remove nearly all autocorrelation between samples. Trace plots were used to assess convergence of the Markov chains. Additionally, we employed the Gelman-Rubin diagnostic[15], which leverages the variations within individual Markov chains as well as across multiple chains from the MCMC samples. This allows us to quantify the potential for further scale reduction, had the MCMC chains been run for an extended period. A potential scale reduction factor (PSRF) less than 1.1 indicates that the MCMC sampling has achieved good convergence.

The CAR prior distribution of the spatial effect $\emptyset_k$ is as follows:

$$\emptyset_k|\emptyset_{-k} \sim N\left(\frac{\rho\sum_{i=1}^{n} w_{ki}\emptyset_i}{\rho\sum_{i=1}^{n} w_{ki}+1-\rho}, \frac{\tau^2}{\rho\sum_{i=1}^{n} w_{ki}+1-\rho}\right)$$

$\emptyset_{-k}$

represents the spatial effect values of all provinces except province k; ρ is the spatial autocorrelation coefficient ($0 \le \rho \le 1$); w_{ki} is the element of the neighborhood weights matrix W; τ^2 is the variance of the spatial effect; n is the number of spatial units.

Results

Temporal trends in MMR

The MMR has significantly decreased over time, dropping from 49.971 per 100 000 (95%CI: 49.903-50.036) in 2005 to a low of 11.500 per 100 000 (95%CI: 11.470-11.531) by the end of 2020 (Figure 1 and Table 2). Furthermore, the inequality in its distribution appears to have decreased, as the variability in the risk of death has diminished, with the interquartile range (IQR) decreasing from 46.082 per 100 000 in 2005 to 4.998 per 100 000 in 2020 (Figure 2), indicating a clear narrowing of regional gaps in maternal mortality over the study period.

Spatial distribution and global spatial autocorrelation of MMR

From the spatial distribution on the map, the MMR shows certain heterogeneity and clustering in spatial distribution, with the western region of China generally being higher than the eastern regions. Through spatial visualization (Figure 3), it can be seen that the spatial pattern of decreasing maternal mortality from east to west in China remained essentially unchanged from 2005 to 2020. From 2005 to 2020, the global Moran's I value for China's MMR ranged from 0.155 to 0.367 (Table 3, all P<0.001), confirming a robust positive spatial autocorrelation. In other words, provinces with high MMR tended to cluster together, and provinces with low MMR also clustered together, rather than being randomly distributed.

Local spatial clustering analysis

Visualization using ArcGIS, we selected four time periods – 2005, 2010, 2015, and 2020 – to conduct local spatial autocorrelation analysis and generated LISA cluster maps for each of these years (Figure 4). A stable high-high cluster of elevated MMR persisted in the western provinces, including Xinjiang, Tibet, and Qinghai, while insignificant clustering was observed in some northeastern, central, and western provinces. The low-low cluster region had emerged in central and eastern provinces, further reinforcing the stepwise decreasing 'east-to-middle-to-west' spatial pattern of MMR.

Bayesian spatial regression analysis

Bayesian spatial models with CAR priors achieved good convergence, as verified by trace plots (Figure 5) and Gelman-Rubin diagnostics (multivariate psrf: 1.03). Detailed results of the Bayesian spatial modeling with CAR priors are presented in Table 4: Except for the Disease Detection Rate in Women Undergoing Pre-Marital Health Checks, which had no significant impact on MMR (RR=1.001, 95%CI: 0.994–1.008, P>0.05), all other included variables exerted significant effects. Specifically, with regard to environmental pollution, Population-Weighted PM2.5 and Per Capita Ammonia Nitrogen Emissions were positively associated with MMR risk, while Per capita chemical oxygen demand emissions were negatively associated with MMR. Indicators related to economic development (Per Capita Consumer Expenditure for the Entire Population and Per Capita Regional Gross Domestic Product), medical resource allocation (Health Technical Personnel in Maternal and Child Health Institutions per 1000 Population and Number of Beds in Medical and Health Institutions per 1000 Population), and prenatal monitoring and examinations (Antenatal care registration rate for pregnant women, Systematic management rate, and Prenatal examination rate) all exerted a favorable, MMR-reducing effect.

Table 1: Variable descriptions and sources

Variable	Data sources
Health Technical Personnel in Maternal and Child Health Institutions per 1000 Population	China Health Statistical Yearbook
Number of Beds in Medical and Health Institutions (per 1000 Population)	China Health Statistical Yearbook
Disease Detection Rate in Women Undergoing Pre-Marital Health Checks	China Health Statistical Yearbook
Antenatal care registration rate for pregnant women (%)	China Health Statistical Yearbook
Prenatal examination rate (%)	China Health Statistical Yearbook
Systematic management rate (%)	China Health Statistical Yearbook
Population-Weighted PM2.5 (ug/m^3)	China Statistical Yearbook
Per Capita Ammonia Nitrogen Emissions (tons)	China Statistical Yearbook
Per capita chemical oxygen demand emissions (tons)	China Statistical Yearbook
Per Capita Disposable Income for the Entire Population (yuan)	China Statistical Yearbook
Per Capita Consumer Expenditure for the Entire Population (yuan)	China Statistical Yearbook
Per Capita Regional Gross Domestic Product (GDP) (yuan per person)	China Statistical Yearbook
End-of-year Resident Population (in tens of thousands)	The Sixth and Seventh National Population Census of China

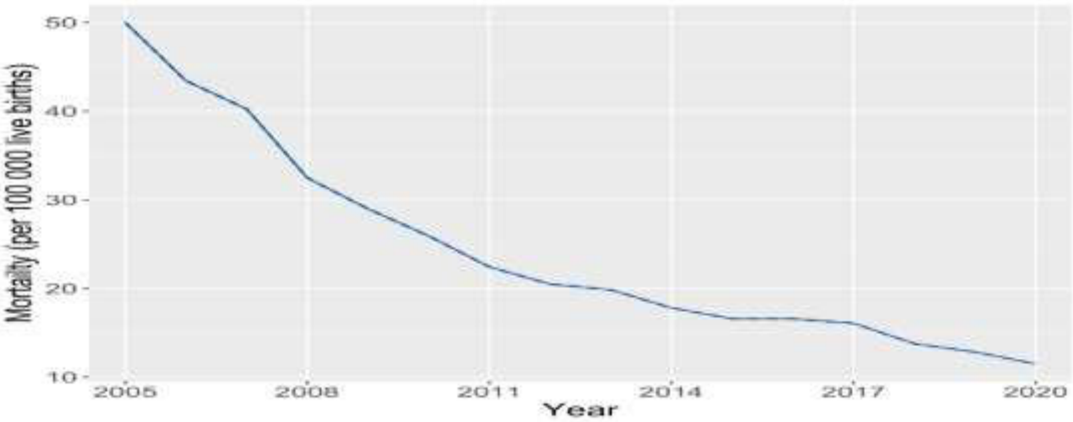


Figure 1: Temporal trends of maternal mortality rate in China, 2005-2020.

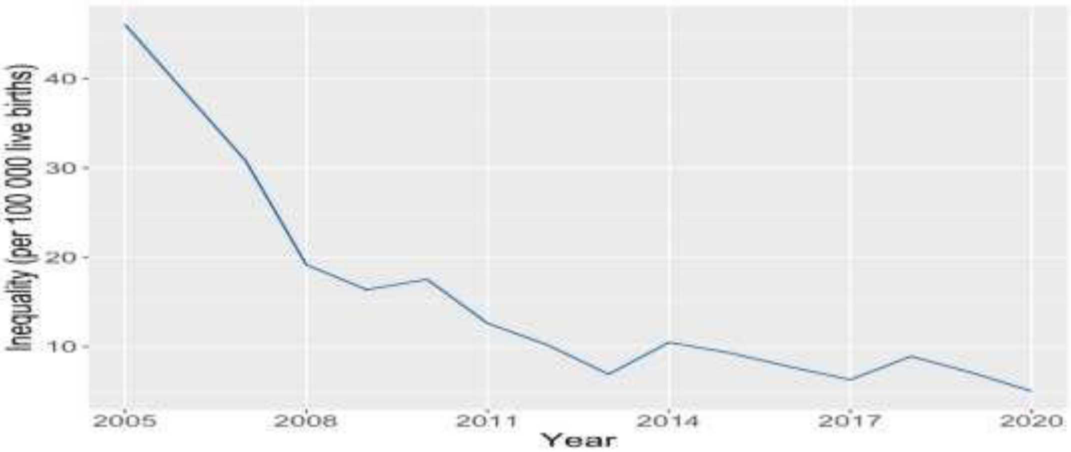
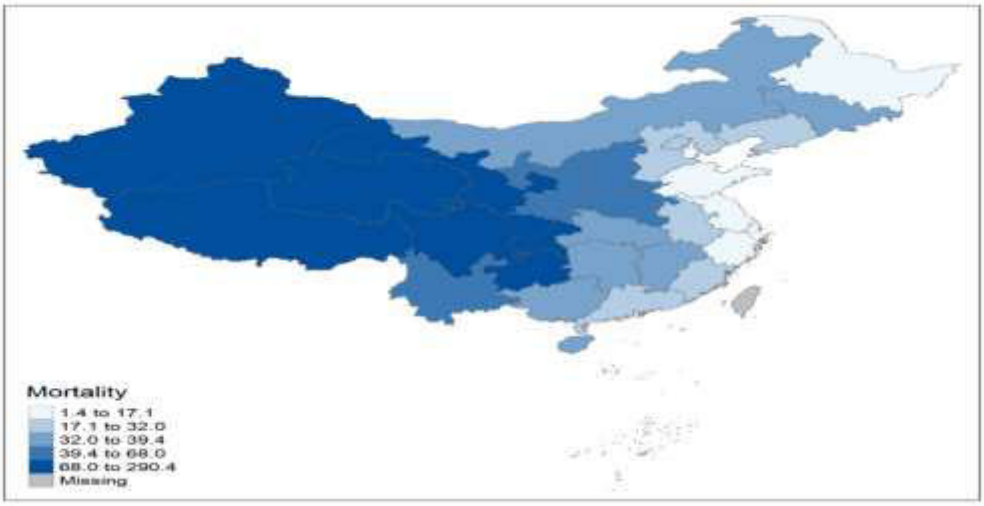


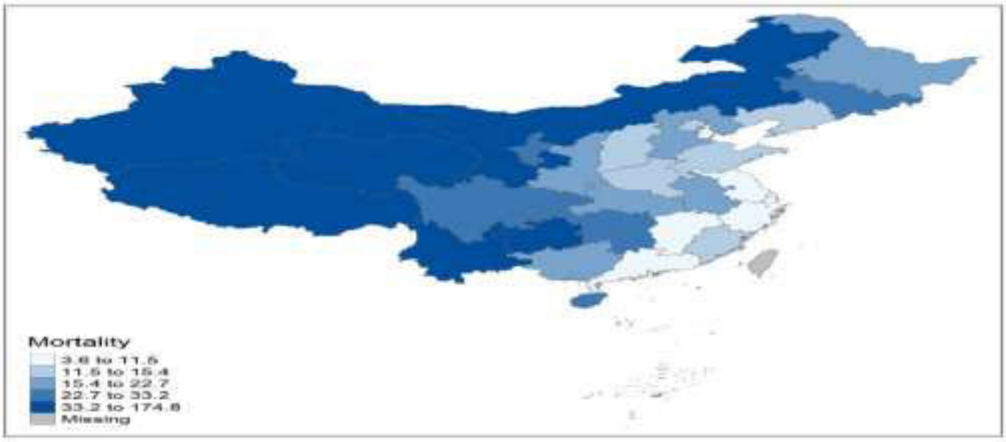
Figure 2: Inequality of maternal mortality rate in China, 2005-2020.

Table 2: Annual estimated maternal mortality rate and its 95% credible interval.

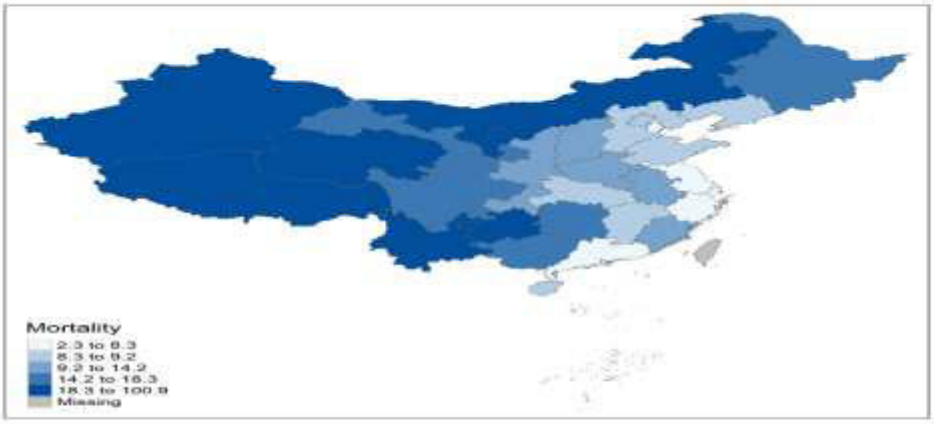
Year	Median	LCI	UCI
2005	49.97052	49.90288	50.03622
2006	43.42201	43.35997	43.48321
2007	40.22839	40.16906	40.28816
2008	32.46862	32.41597	32.52163
2009	28.98785	28.93883	29.03694
2010	25.91728	25.8715	25.96283
2011	22.43394	22.39047	22.47613
2012	20.49027	20.45017	20.53071
2013	19.8473	19.80614	19.88728
2014	17.81288	17.77528	17.85057
2015	16.58298	16.54636	16.61929
2016	16.59317	16.55642	16.62999
2017	16.07294	16.03671	16.1085
2018	13.78341	13.75028	13.81631
2019	12.84656	12.81447	12.87837
2020	11.5003	11.46986	11.5307



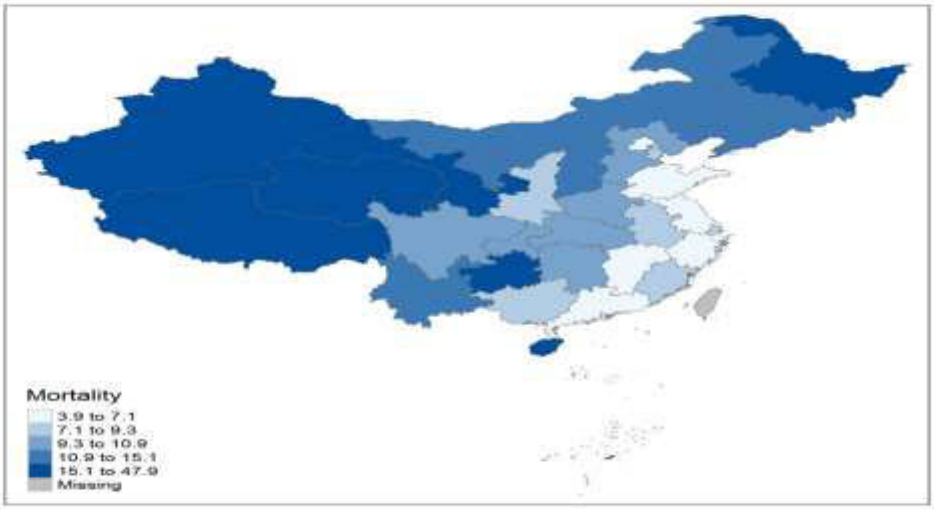
(a)



(b)



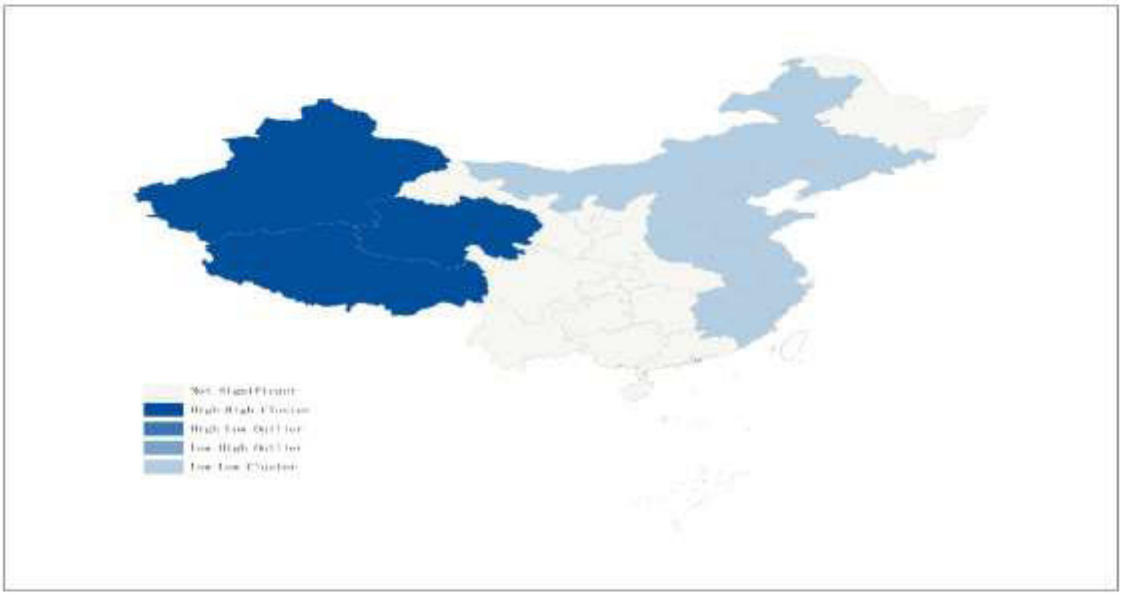
(c)



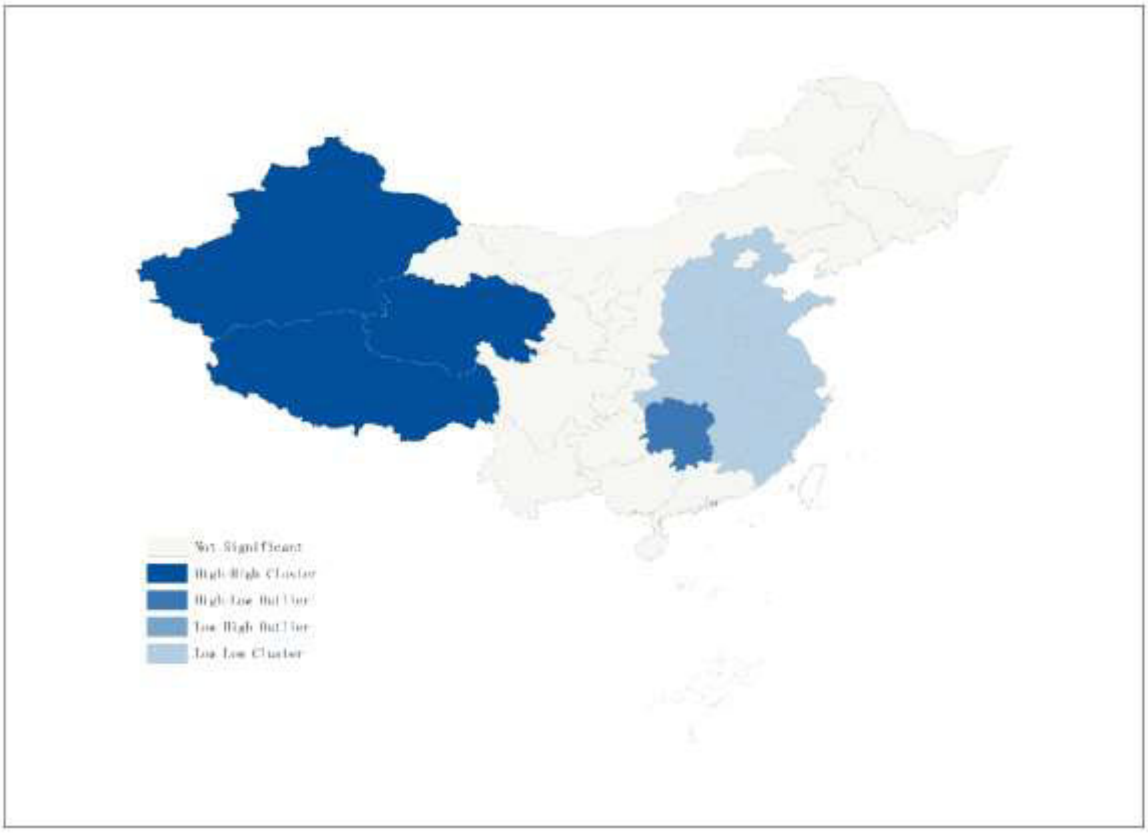
(d)

Table 3: Results of global Moran's I of MMR in China from 2005 to 2020

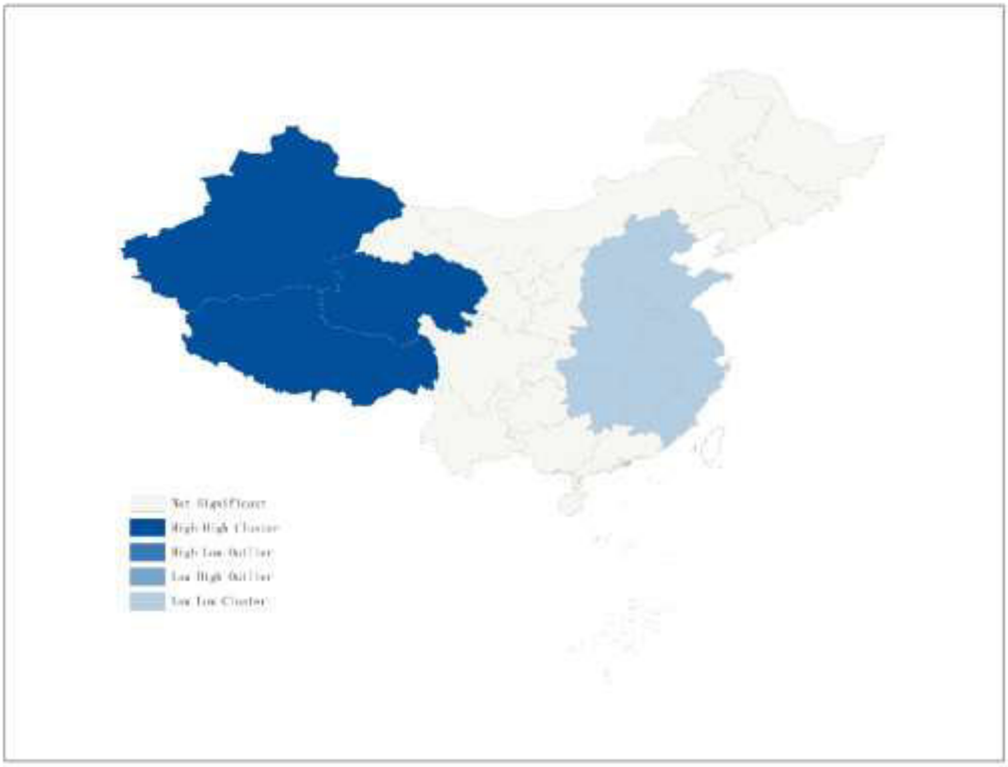
Year	Moran'I	*P* value
2005	0.36664	<0.001
2006	0.35075	<0.001
2007	0.257	<0.001
2008	0.22129	<0.001
2009	0.1545	<0.001
2010	0.19178	<0.001
2011	0.21265	<0.001
2012	0.16053	<0.001
2013	0.20822	<0.001
2014	0.27096	<0.001
2015	0.28872	<0.001
2016	0.23994	<0.001
2017	0.21665	<0.001
2018	0.32533	<0.001
2019	0.24257	<0.001
2020	0.28651	<0.001


Not Significant
High-High Cluster
High-Low Outlier
Low-High Outlier
Low-Low Cluster

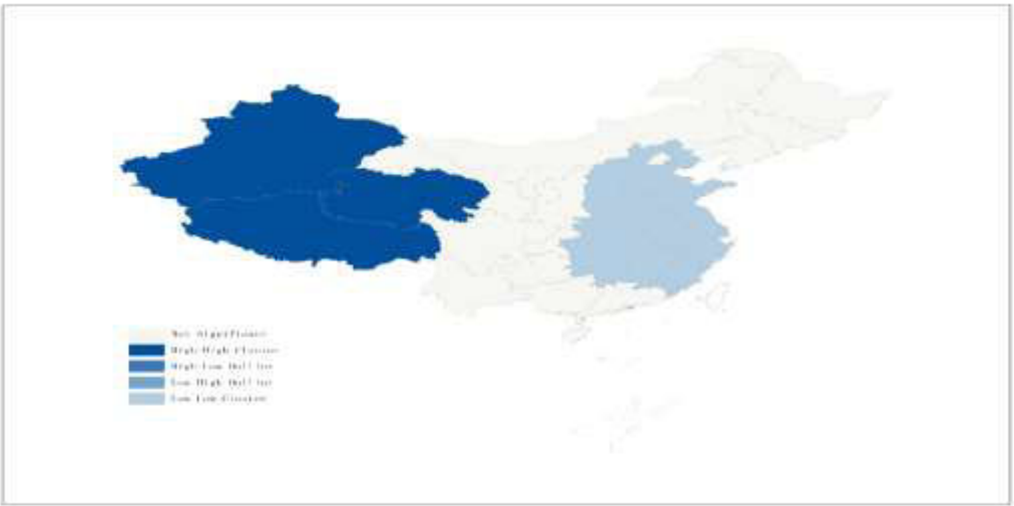
(a)


Not Significant
High-High Cluster
High-Low Outlier
Low-High Outlier
Low-Low Cluster

(b)



(c)



(d)

Figure 4: LISA cluster map of the spatial distribution of maternal mortality rate in China (a) 2005, (b) 2010, (c) 2015, and (d) 2020.

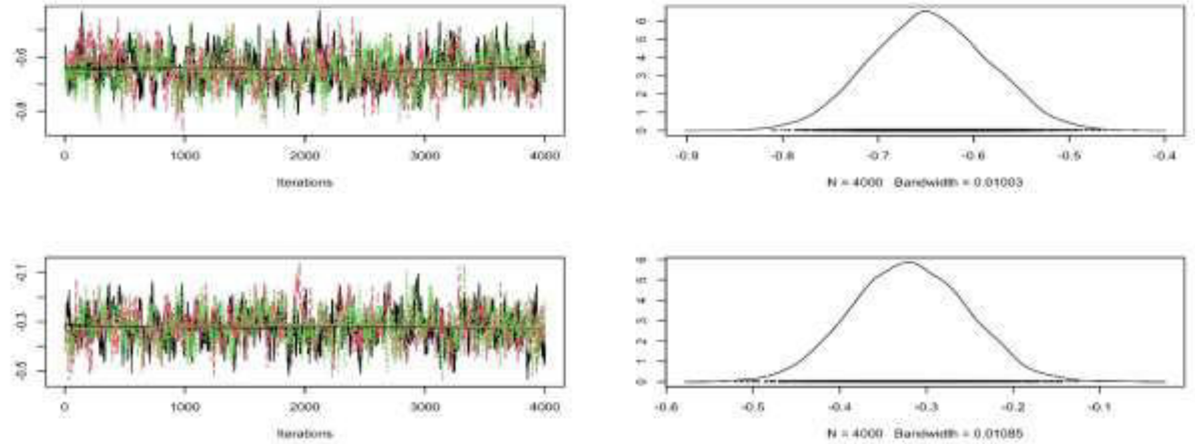


Figure 5: Trace plots employing to assess convergence of the Markov chains.

Table 4: Analysis of influencing factors by performing a bayesian spatial modeling with conditional autoregressive priors.

Variable	Risk ratio	LCI	UCI	Sd
Health Technical Personnel in Maternal and Child Health Institutions per 1000 Population	0.809	0.798	0.819	0.173
Number of Beds in Medical and Health Institutions per 1000 Population	0.890	0.865	0.914	0.232
Disease Detection Rate in Women Undergoing Pre-Marital Health Checks	1.001	0.994	1.008	0.046
Population-Weighted PM2.5(ug/m^3)	1.312	1.295	1.330	0.188
Per Capita Ammonia Nitrogen Emissions (tons)	1.040	1.018	1.061	0.231
Per capita chemical oxygen demand emissions (tons)	0.971	0.960	0.982	0.069
Per Capita Consumer Expenditure for the Entire Population (yuan)	0.449	0.418	0.482	0.179
Per Capita Regional Gross Domestic Product (GDP) (yuan per person)	0.728	0.699	0.759	0.174
Antenatal care registration rate for pregnant women (%)	0.931	0.912	0.952	0.159
Systematic management rate (%)	0.895	0.877	0.914	0.171
Prenatal examination rate (%)	0.951	0.932	0.971	0.158

Discussion

This study examines the spatiotemporal patterns and determinants of MMR across China's 31 provincial-level administrative units from 2005 to 2020. A key scientific contribution of this work is the quantification of persistent spatial clustering in MMR using global and local spatial autocorrelation analyses, which fills the gap of insufficient subnational spatial heterogeneity exploration in previous Chinese maternal mortality research. While national MMR showed a sharp decline, geographic disparities remained significant. Bayesian spatial regression revealed that all factors except premarital disease detection rate significantly affected MMR, among which per capita consumer expenditure was identified as the dominant protective factor, a finding that strengthens causal inference for socioeconomic drivers of maternal health.

Prior research has demonstrated a positive association between the number of healthcare personnel per capita and health status.[16-18] Cameron and colleagues found that the key factors contributing to maternal mortality were the number of physicians working in community health centers or villages, and the distance to the nearest hospital.[19] Building on this, our study further demonstrates that the number of maternal and child health workers and hospital beds per 1,000 population remain strong protective factors, even after controlling for spatial correlation. This confirms that expanding healthcare resources directly reduces the risk of maternal mortality, rather than merely reflecting confounding socioeconomic factors. This finding carries clear policy implications: sustained investment in midwifery staffing and obstetric care capacity in high-risk western regions is critical to sustaining the decline in maternal mortality.

Our findings revealed a substantial inverse relationship between a region's level of economic development and its maternal mortality rate. This phenomenon could stem from the reality that economically affluent regions tend to have more robust medical infrastructure, ample healthcare resources, and superior quality of care delivery. Additionally, higher economic development often coincides with better health literacy and education levels, fostering greater awareness about disease prevention and risk mitigation. In essence, economic progress plays a pivotal role in elevating the health status of women, including expectant mothers, thereby contributing to reductions in MMR.[20-23] Unlike prior studies that only reported inverse associations, our Bayesian spatial model quantifies the magnitude of this effect (RR = 0.449) and isolates its independent contribution after adjusting for environment, medical resources, and prenatal care. This conclusion supports China's policy of coordinated regional development and targeted assistance to underdeveloped areas: through financial transfer payments and maternal and child health policy inclination, the government has promoted the balanced allocation of medical resources, which is consistent with the principle of "promoting the synchronous and coordinated development of women's cause with economic and social development".[24] Our quantified effect size can provide a scientific basis for optimizing the intensity of policy support and improving the efficiency of resource allocation.

The growth in China's economic levels has not increased the disparities in MMR across different socioeconomic regions.[25] [26] This is attributed to China's assistance to economically or medically underdeveloped areas. Through regional maternal and child healthcare policy initiatives and substantial financial assistance programs, the government swiftly increased the rate of hospital-based deliveries from an average of 85.9% in 2005 to 99.9% in 2017 and maintained it until 2020. However, merely utilizing hospital delivery services did not aid in eliminating socioeconomic-related inequalities in MMR. Studies have revealed substantial variations in the quality of care provided for common clinical conditions across China's tertiary hospitals.[27] Therefore, advanced medical equipment and skilled healthcare personnel should be deployed to hospitals in some underdeveloped areas in order to improve their healthcare standards. These efforts are conducive to further narrowing the regional disparities in maternal mortality. To address this gap, relevant policies have been continuously optimized: the Notice on Strengthening the Management of Midwifery Services requires improving the quality of midwifery services, strengthening skills training for obstetric personnel, and promoting the construction of childbirth-friendly hospitals.[28] Although some regions have implemented policies such as increasing medical insurance subsidies for maternal delivery and prenatal care, as well as establishing green channels for the treatment of critically ill parturients, our study underscores the need to further deepen these policies. The priority should be improving the quality of medical services in less developed regions and expanding the coverage of delivery services.

The detrimental Impacts of $PM_{2.5}$ on human health have been extensively documented.[29-32] Hayes and colleagues found that $PM_{2.5}$ air pollution was correlated to increased mortality from specific cardiovascular diseases,[32] and this is particularly relevant to maternal health as cardiovascular causes of death are among the common reasons for maternal mortality,[33] [34] Other environmental pollution can also be harmful to the human body and increase the MMR. However, environmental pollution levels do not just indicate the extent of air, water, or soil quality issues in a given area, but also indirectly signify the region's stage of economic advancement. This may partly explain why the increase in Per capita chemical oxygen demand emissions did not lead to an increase in the MMR.

In China, especially in regions where antenatal care needs to be strengthened, pregnant women need to be encouraged to choose their delivery hospital early in pregnancy and establish a maternal health record at that chosen facility. This record documents prenatal examination results, helps remind women of scheduled antenatal care visits, and allows for systematic and comprehensive management of the pregnancy and fetal development throughout the entire process.

Limitations

Our study has some limitations. Firstly, we obtained provincial MMR and other data from some government publications and did not have sufficient data to support further county-level spatial statistical analysis. Secondly, this type of data precluded us from making causal inferences about risk factors at the individual level. Thirdly, the factors examined in this study could be more comprehensive; in addition to the 11 factors included in this study, factors such as the maternal individual health status, presence of underlying conditions, BMI, quality of healthcare, and natural environment should be the focus of future research.

Conclusions

This study aimed to investigate provincial disparities, regional inequalities, and associated determinants of maternal mortality in China from 2005 to 2020, addressing the gap of insufficient spatial analyses at the local level. Our findings confirmed a significant nationwide decline in maternal mortality, alongside pronounced spatial clustering: higher mortality rates were observed in western provinces, while lower rates were seen in eastern and central regions. Per capita consumption expenditure emerged as the most influential determinant. A key implication is that targeted interventions in western China are essential to narrow regional gaps, and our results provide actionable insights for health policy formulation in China and global efforts toward maternal health equity.

Acknowledgment

None

Conflict of interest

The authors declare no competing interests.

Funding

This work was supported by the Wuxi Young Scientific and Technological Talents Support Program (TJXD-2025-241), Youth Research Project of Wuxi Nursing Society (Q202505) and the Nursing Research "Seedling-Raising" Program from the Affiliated Hospital of Jiangnan University (HL-25-M03)

Contribution of authors

Jue Tang Contributed to study conception, collected the data, performed statistical data analysis, and drafted the initial manuscript.Fei-Hong Hu Conceived and designed the overall research framework, collected the data, performed statistical data analysis, and reviewed and revised the manuscript.

Data availability

All relevant data are disclosed in the paper, its associated figures, and the tables. Raw data are available from the corresponding author upon request or can be consulted in the China Statistical Yearbook

References

1. Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division: executive summary. World Health Organization. Available at: https://www.who.int/publications/i/item/9789240069251. Accessed March 16, 2024.
2. Souza JP, Day LT, Rezende-Gomes AC, Zhang J, Mori R, Baguiya A, Jayaratne K, Osoti A, Vogel JP, Campbell O, Mugerwa KY, Lumbiganon P, Tunçalp Ö, Cresswell J, Say L, Moran ACandOladapo OT. A global analysis of the determinants of maternal health and transitions in maternal mortality. *Lancet Glob Health* 2024;12(2):e306-e16.
3. Ward ZJ, Atun R, King G, Sequeira Dmello BandGoldie SJ. Simulation-based estimates and projections of global, regional and country-level maternal mortality by cause, 1990-2050. *Nature medicine* 2023;29(5):1253-61.
4. National Health Commission of the People's Republic of China. China health statistics yearbook. Beijing: Peking Union Medical College Press; 2022.
5. Luo M, Ding H, Chen X, Luo P, Dong EandLi S. Socioeconomic and health system determinants of maternal health inequities across Chinese provinces

(2009-2021): a multivariate meta-regression analysis of regional heterogeneity in underlying mechanisms. *Frontiers in public health* 2026;14:1722508.
6. Liang J, Li X, Kang C, Wang Y, Kulikoff XR, Coates MM, Ng M, Luo S, Mu Y, Wang X, Zhou R, Liu X, Zhang Y, Zhou Y, Zhou M, Li Q, Liu Z, Dai L, Li M, Zhang Y, Deng K, Zeng X, Deng C, Yi L, Zhu J, Murray CJLandWang H. Maternal mortality ratios in 2852 Chinese counties, 1996-2015, and achievement of Millennium Development Goal 5 in China: a subnational analysis of the Global Burden of Disease Study 2016. *Lancet (London, England)* 2019;393(10168):241-52.
7. Li CL, Jiang M, Huang KC, Li JandXu LG. The trends of maternal mortality ratios and cause pattern in 34 Chinese provinces, 1990-2017. *BMC public health* 2022;22(1):1369.
8. Li J, Liang J, Wang J, Ren Z, Yang D, Wang Y, Mu Y, Li X, Li M, Guo YandZhu J. Spatiotemporal trends and ecological determinants in maternal mortality ratios in 2,205 Chinese counties, 2010-2013: A Bayesian modelling analysis. *PLoS medicine* 2020;17(5):e1003114.
9. Gao Y, Zhou H, Singh NS, Powell-Jackson T, Nash S, Yang M, Guo S, Fang H, Alvarez MM, Liu X, Pan J, Wang YandRonsmans C. Progress and challenges in maternal health in western China: a Countdown to 2015 national case study. *The Lancet Global health* 2017;5(5):e523-e36.
10. Li D, Yu C, Song C, Ning W, Xu Y, Ge H, Lin S, Zhou W, Lu Y, Wang X, Hu Z, Lin YandWu J. Maternal mortality ratio in Jiangsu Province, China: recent trends and associated factors. *BMC pregnancy and childbirth* 2021;21(1):447.
11. Tian FandPan J. Hospital bed supply and inequality as determinants of maternal mortality in China between 2004 and 2016. *International journal for equity in health* 2021;20(1):51.
12. Li Y, Zhang Y, Fang S, Liu S, Liu X, Li M, Liang HandFu H. Analysis of inequality in maternal and child health outcomes and mortality from 2000 to 2013 in China. *International journal for equity in health* 2017;16(1):66.
13. Luo C, Wang Y, Su Q, Zhu J, Tang S, Bergquist R, Zhang ZandHu Y. Mapping schistosomiasis risk in Southeast Asia: a systematic review and geospatial analysis. *International journal of epidemiology* 2023;52(4):1137-49.
14. Alene KA, Python A, Weiss DJ, Elagali A, Wagaw ZA, Kumsa A, Gething PWandClements ACA. Mapping tuberculosis prevalence in Ethiopia using geospatial meta-analysis. *International journal of epidemiology* 2023;52(4):1124-36.
15. Gelman A, Carlin JB, Stern HS, Dunson DBandRubin DB. Bayesian Data Analysis, 3rd Ed. 2014.
16. Yip W, Fu H, Chen AT, Zhai T, Jian W, Xu R, Pan J, Hu M, Zhou Z, Chen Q, Mao W, Sun QandChen W. 10 years of health-care reform in China: progress and gaps in Universal Health Coverage. *Lancet (London, England)* 2019;394(10204):1192-204.
17. Liu W, Liu Y, Twum PandLi S. National equity of health resource allocation in China: data from 2009 to 2013. *International journal for equity in health* 2016;15:68.
18. McCaw-Binns A, Standard-Goldson A, Ashley D, Walker GandMacGillivray I. Access to care and maternal mortality in Jamaican hospitals: 1993-1995. *International journal of epidemiology* 2001;30(4):796-801.
19. Cameron L, Contreras Suarez DandCornwell K. Understanding the determinants of maternal mortality: An observational study using the Indonesian Population Census. *PloS one* 2019;14(6):e0217386.
20. Mehta A, Spitz J, Sharma S, Bonomo J, Brewer LC, Mehta LSandSharma G. Addressing Social Determinants of Health in Maternal Cardiovascular Health. *The Canadian journal of cardiology* 2024.
21. Dudukina E, Horváth-Puhó E, Sørensen HTandEhrenstein V. Association between pregnancy affected by vaginal bleeding and women's mortality: A cohort study. *BJOG : an international journal of obstetrics and gynaecology* 2024;131(2):175-88.
22. Laine JE, Baltar VT, Stringhini S, Gandini M, Chadeau-Hyam M, Kivimaki M, Severi G, Perduca V, Hodge AM, Dugué PA, Giles GG, Milne RL, Barros H, Sacerdote C, Krogh V, Panico S, Tumino R, Goldberg M, Zins M, Delpierre CandVineis P. Reducing socio-economic inequalities in all-cause mortality: a counterfactual mediation approach. *International journal of epidemiology* 2020;49(2):497-510.
23. Li C, Zeng L, Dibley MJ, Wang D, Pei LandYan H. Evaluation of socio-economic inequalities in the use of maternal health services in rural western China. *Public health* 2015;129(9):1251-7.
24. National Program for Women's Development (2021–2030). The State Council of China. Available at: http://www.gov.cn/zhengce/zhengceku/2021-09/27/content_5639412.htm. Accessed April 22, 2026.
25. Feng XL, Zhu J, Zhang L, Song L, Hipgrave D, Guo S, Ronsmans C, Guo YandYang Q. Socio-economic disparities in maternal mortality in China between 1996 and 2006. *BJOG : an international journal of obstetrics and gynaecology* 2010;117(12):1527-36.
26. Zhang M, Qu H, Xia J, Hui X, Shi C, Xu F, He J, Cao YandHu M. Trends, influencing factors and prediction analysis of under-five and maternal mortality rates in China from 1991 to 2020. *Frontiers in public health* 2023;11:1198356.
27. Yin C, Li J, Meng W, Hou S, Liu D, Liu M, Yu L, Guo R, Han XandLiu M. Trends in care quality in China from 2011 to 2017: An analysis based on the National Specific (Single) Disease Monitoring System. *Journal of global health* 2023;13:04045.
28. Strengthening the Management Project of Midwifery Services. National Health Commission General Office. Available at:

https://www.gov.cn/zhengce/zhengceku/202403/content_6942014.htm. Accessed April 22, 2026.

29. Lavigne E, Yasseen AS, 3rd, Stieb DM, Hystad P, van Donkelaar A, Martin RV, Brook JR, Crouse DL, Burnett RT, Chen H, Weichenthal S, Johnson M, Villeneuve PJandWalker M. Ambient air pollution and adverse birth outcomes: Differences by maternal comorbidities. *Environmental research* 2016;148:457-66.
30. Klepac P, Locatelli I, Korošec S, Künzli NandKukec A. Ambient air pollution and pregnancy outcomes: A comprehensive review and identification of environmental public health challenges. *Environmental research* 2018;167:144-59.
31. Bo Y, Yu T, Chang LY, Guo C, Lin C, Zeng Y, Huang B, Tam T, Lau AKH, Wong SYSandLao XQ. Combined effects of chronic PM2.5 exposure and habitual exercise on cancer mortality: a longitudinal cohort study. *International journal of epidemiology* 2022;51(1):225-36.
32. Hayes RB, Lim C, Zhang Y, Cromar K, Shao Y, Reynolds HR, Silverman DT, Jones RR, Park Y, Jerrett M, Ahn JandThurston GD. PM2.5 air pollution and cause-specific cardiovascular disease mortality. *International journal of epidemiology* 2020;49(1):25-35.
33. Baqui AH, Khanam R, Mitra DK, Begum N, Rahman MH, Moin MI, Quaiyum MA, Tshefu A, Otomba J, Kalonji M, Ngttwo A, Ngaima S, Kirkwood B, Shannon C, Hurt L, Soremektin S, O'Leary M, Arnenga-Etego S, Edmond K, Newton S, Mohan SB, Mazurnder S, Taneja S, Bhatia K, Dube B, Kaur J, Bhandari N, Kumar V, Kumar A, Patil P, Mishra S, Kumar A, Ghosh AK, Esamai F, Marete I, Gisore P, Sunday V, Nisar I, Jehan F, Ilyas M, Mehmood U, Muhammad K, Zaidi A, Soofi S, Ariff S, Wasan Y, Ahmed L, Bhutta ZA, Masanja H, Smith E, Muhihi A, Mlay E, Fawzi W, Sazawal S, Ali SM, Dutta A, Dhingra U, Deb S, Hamer DH, Semrau KEA, Herlihy J, Yeboah-Antwi K, Grogan C, Biemba G, Bahl R, Manu A, Yoshida SandAlliance Maternal Newborn Hlth I. Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. *Lancet Global Health* 2018;6(12):E1297-E308.
34. Kallianidis AF, Schutte JM, Schuringa LEM, Beenakkers ICM, Bloemenkamp KWM, Braams-Lisman BAM, Cornette J, Kuppens SM, Rietveld AL, Schaap T, Stekelenburg J, Zwart JJandvan den Akker T. Confidential enquiry into maternal deaths in the Netherlands, 2006-2018. *Acta obstetricia et gynecologica Scandinavica* 2022;101(4):441-49