

Article

Construct Overlap Inflates Apparent Economic-Capacity Alignment: Evidence from a Hebei City Panel, 2014–2023

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Abstract

Index-based urban sustainability studies often ask whether urban resilience and economic development evolve harmoniously, but the answer is unreliable when the two constructs contain the same economic indicators. A targeted audit of recent Chinese coupling studies shows that economic variables are commonly embedded in urban-resilience systems without a reported construct-overlap weight check. Using Hebei, China, as a measurement-validity test rather than as another provincial economic-growth case, this study analyzes a balanced 2014–2023 panel of 11 prefecture-level cities. Duplicated economic concepts account for 44.4% of the baseline resilience-index entropy weight and 88.2% of the baseline economic-index weight, indicating substantial mechanical exposure in the resilience-development correlation (Pearson $r = 0.953$). We, therefore, construct a measured non-economic service-infrastructure-ecological resilience-capacity index and a separate economic-development index. The redesigned index is not a comprehensive urban-resilience measure because it excludes governance, social capital, emergency response, hazard exposure, social vulnerability, and institutional adaptation. Removing only the shared resilience-side components lowers the all-year correlation to 0.783; after full redesign, it is 0.562. In constant 2014 prices, economic development rises sharply from 2014 to 2023, whereas measured non-economic resilience capacity improves modestly. Robustness tests separate stable city findings from measurement-sensitive ones: Langfang and Shijiazhuang remain economy-ahead across all 13 selected specifications, while Cangzhou does so in 11 of 13, Tangshan is economy-ahead in 11 of 13 selected specifications but sensitive to the gas-supply proxy, and Qinhuangdao and Xingtai remain measured-capacity-ahead across all specifications. The measured non-economic resilience capacity shows a detectable global autocorrelation under queen contiguity, whereas a mismatch shows no statistically detectable global autocorrelation under the tested specifications. The primary contribution is methodological: a construct-overlap audit and directional mismatch diagnosis that identifies relative differences between economic development and measured public-service, infrastructure, utility, and ecological resilience capacity. These diagnostics do not establish a causal conversion failure.

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1. Introduction

Urban resilience has moved from ecological systems theory into urban sustainability research because cities now face overlapping economic, infrastructural, environmental, and public-health disturbances. The concept's lineage begins with resilience as the capacity of a system to absorb disturbance and retain structure or function [1]. In urban studies, this idea has expanded to include the capacity of urban systems, institutions, infrastructure, communities, economies, and ecosystems to prepare for, absorb, recover from, and adapt to shocks and stresses [2–5]. The emerging polycrisis literature emphasizes causal interactions among crises across sectors and spatial scales [6,7]. Such real-world interdependence does not justify construct overlap in an index: economic and resilience systems may be causally connected while their indicators remain analytically distinct. This breadth is useful because cities are coupled socio-ecological–technical systems, but it also creates a measurement problem: if resilience is defined too broadly, almost any desirable urban attribute can be inserted into the index.

The tension between resilience and sustainability is well recognized. Resilience is not identical to sustainability, and a resilient system is not necessarily just, low-carbon, inclusive, or sustainable [8–10]. Sustainable-city research increasingly emphasizes systems thinking and transformation rather than isolated sectoral improvement. Conversely, a city may become more prosperous or more efficient while remaining fragile under infrastructure stress, climate hazards, public-health shocks, or ecological degradation. This distinction is especially important in empirical studies that compare urban resilience with economic development. Economic capacity may support resilience investments, but the existence of economic growth does not prove that public-service, infrastructure, and ecological capacities have kept pace. Recent ecological-economic resilience research provides a complementary framing of coordination between ecological and economic resilience systems [11]. The empirical construct used here excludes governance, social capital, emergency response, hazard exposure, social vulnerability, and institutional adaptation because consistent city-year series were unavailable; it should not be interpreted as comprehensive urban resilience.

Chinese urban sustainability research has made extensive use of composite indices and coupling-coordination models to evaluate relationships among urbanization, resilience, ecological quality, digital economy, land development, tourism economy, and regional development [12–20]. These studies are valuable because they make regional sustainability patterns visible and policy-relevant. They also create a crowded field. A Hebei-only paper cannot plausibly claim novelty merely by measuring a coupling-coordination degree between urban resilience and economic development. Prior work has already assessed urban resilience and subsystem coupling in the Beijing–Tianjin–Hebei urban agglomeration [16], urbanization-resilience coupling in the Yangtze River Economic Belt [13], digital-economy and eco-economic resilience coupling in Beijing–Tianjin–Hebei [14], tourism economy and resilience coupling in Beijing–Tianjin–Hebei [15], and urbanization-ecological resilience coupling in the Yangtze River Delta [17]. A related *Sustainability* article has also examined Hebei's industrial structure and economic growth from a sectoral-reallocation perspective [21], while other recent studies have coupled urban resilience with the tourism economy, low-carbon development, and multidimensional urban development in Chinese city regions [22–24]. A manuscript that simply repeats the Hebei setting, an economic-development theme, and a map-based index narrative would, therefore, have limited incremental value.

The more defensible contribution lies in measurement validity. The present study is not an extension of the Hebei industrial-structure paper and does not reuse its sectoral advance coefficients, Moore index, industrial-structure upgrading measures, or industrial restructuring argument. It asks a different question: whether urban resilience and eco-

economic development are being measured as distinct constructs before their relationship is interpreted. Coupling models are interpretable only if the coupled systems are conceptually distinct. If GDP, fiscal revenue, disposable income, fixed-asset investment, wages, or retail sales appear on both sides of the analysis, the estimated relationship is partly built into the measurement design. This is not a minor technical issue. Composite-index methods are sensitive to indicator selection, normalization, weighting, aggregation, and robustness choices [25,26]. The same concern appears in resilience assessment: the index must be clear about which capacities are being measured and which are being treated as outcomes, drivers, or contextual conditions [27–29]. Without construct separation, a coupling-coordination score can convert a tautology into a policy narrative.

Hebei is an appropriate setting for testing this problem. The province surrounds Beijing and Tianjin and occupies a strategic position in the Beijing–Tianjin–Hebei coordinated development region. Its city system includes the provincial capital Shijiazhuang, heavy-industrial and port-linked Tangshan, the Beijing–Tianjin corridor cities of Langfang and Baoding, coastal Qinhuangdao and Cangzhou, southern industrial cities such as Handan and Xingtai, agricultural and transport cities such as Hengshui, and northern ecological-fringe cities such as Zhangjiakou and Chengde. This structure creates a real sustainability question: do economically stronger cities also show stronger measured non-economic service, infrastructure, utility, and ecological resilience capacity, or do they stand ahead economically while these capacities lag in relative terms?

This study, therefore, reframes the project. It does not ask whether an all-inclusive urban-resilience index is coordinated with an economic-development index. Instead, it asks: how did economic development and measured non-economic resilience capacity evolve across Hebei's prefecture-level cities from 2014 to 2023, and which cities show mismatch after economic indicators are removed from the resilience construct?

The paper makes four contributions. The first and primary contribution is methodological: it audits the baseline measurement design and uses nested models to distinguish overlap removal from subsequent construct redesign. Second, it constructs a non-overlapping city-panel measurement system that separates economic development from measured health-service, infrastructure, utility, and ecological-service resilience capacity. Third, it reports mismatch trajectories, 2023 city typologies, spatial autocorrelation diagnostics, robustness checks, a rank-gap check, a 180-specification multiverse, and obstacle factors rather than relying on a single coupling score. Fourth, it uses Hebei as an empirical demonstration and policy diagnosis for a broader methodological point in urban sustainability research: before asking whether two systems are coordinated, researchers must verify that the systems have not been made coordinated by shared indicators.

2. Materials and Methods

2.1. Study Area, Panel Construction, and Data Provenance

This study uses an ecological city-panel design for all 11 prefecture-level cities in Hebei: Baoding, Cangzhou, Chengde, Handan, Hengshui, Langfang, Qinhuangdao, Shijiazhuang, Tangshan, Xingtai, and Zhangjiakou. The prefecture-level city is the appropriate unit for the research question because Hebei's economic, infrastructure, public-service, and city-construction statistics are reported and governed largely at this scale. The inference is, therefore, explicitly city-level. The analysis does not claim to measure household resilience, neighborhood vulnerability, firm adaptability, or asset-level infrastructure exposure.

The analytic period is 2014–2023, yielding a balanced panel of 110 city-year observations. This window was selected because the required indicators are available with consistent definitions and units for all 11 cities over these years. A longer series would weaken rather than strengthen the design because the most recent city-level observations were not

documented consistently across all indicators. The final decade-long panel is, therefore, defined by source consistency rather than maximum possible length. The period also spans economic restructuring, Beijing–Tianjin–Hebei coordinated development, the COVID-19 shock, and early recovery. Together, consistent source coverage and these substantive developments provide the basis for selecting the study window and context for interpretation. The 11-city design limits statistical power and generalization beyond Hebei.

The panel was assembled from the 2015–2024 annual editions of the Hebei Statistical Yearbook, reporting 2014–2023 observations, and yearbook-derived city extracts [30]. The annual table families cover population, prefecture GDP, public-budget revenue, urban disposable income and wages, retail sales, fixed-asset investment, medical institutions and beds, electricity, gas, municipal roads, green space, environmental sanitation, R&D, FDI, and urban population. All 11 cities were retained; city names were harmonized by trimming whitespace and removing the *shi* suffix, years were converted to integers, and indicator and control records were joined one-to-one by city and year. Only indicators consistently available for all cities and years were retained. Hospital beds and park/green area were divided by population to obtain per-10,000-resident measures; electricity, gas, fiscal revenue, retail sales, fixed-asset investment, R&D, and FDI were converted to per-resident measures; urbanization was calculated as urban population divided by total population. Quality checks included duplicate-key and unmatched-record checks, unit review, missingness checks, range inspection, and comparison of duplicate or similarly named indicators. The final panel contains no missing observations. Before normalization or weighting, all yuan-denominated index variables and the yuan-denominated R&D control were converted to constant 2014 prices with a chained Hebei provincial CPI. Annual CPI changes for 2015–2023 were 0.9%, 1.5%, 1.7%, 2.4%, 3.0%, 2.1%, 1.0%, 1.8%, and 0.6%, respectively [31]; a common provincial deflator was used because a complete city-specific series is unavailable. One unit correction was necessary: the economic retail-sales field labeled “100 million yuan” was numerically identical to the explicit 10,000-yuan field in all 110 observations, and that explicit field equaled the correctly scaled resilience-side 100-million-yuan series multiplied by 10,000, so the final analysis uses the explicit 10,000-yuan field and converts it to yuan per resident. Indicator definitions, units, transformations, source families, and weights are reported in Supplementary Table S1.

2.2. Construct Audit and Non-Overlapping Indicator Design

The study began with a construct-validity audit rather than with index estimation. To ensure that the problem was not merely a local defect in the original Hebei draft, we first reviewed a targeted set of recent Chinese urban-resilience and coupling-coordination studies that are close to the manuscript’s topic and venue context. The audit was not designed as a systematic review. We prioritized recent Chinese city, city-region, and urban-agglomeration studies on urban resilience, urbanization-resilience, tourism-resilience, low-carbon-resilience, or related coupling/evaluation topics; retained papers that reported extractable indicator systems or paired constructs; and extracted the coupled system, economic content inside the resilience construct, and whether a construct-overlap weight audit was reported. The narrower purpose was to determine whether economic variables are commonly embedded inside urban-resilience indicator systems and whether comparable studies report an explicit construct-overlap test before interpreting coordination. The reviewed studies show a recurring pattern: resilience systems often contain economic subsystems or economic-development indicators, while the relationship being modeled also concerns urbanization, tourism economy, low-carbon development, or regional economic transformation. Table 1 reports the targeted comparator audit. None of the audited studies reports the weight share of duplicated economic concepts before esti-

inating coupling or coordination. The table is therefore an audit of construct-overlap risk in close comparators, not a prevalence estimate and not a claim that the cited papers are invalid.

Table 1. Targeted audit of construct-overlap risk in comparable Chinese urban-resilience studies.

Study	Coupled or Evaluated System	Economic Content Inside the Resilience Construct	Reported Construct-Overlap Weight Audit
Zhang and Li [12]	Urban resilience and tourism economy in Beijing–Tianjin–Hebei	Economic resilience indicators include per capita GDP, retail sales, tertiary-industry share, and fiscal revenue	No
Peng et al. [15]	Urbanization and urban resilience in the Yangtze River Delta	Both systems include economic, social, ecological, and land or infrastructure dimensions	No
Pan et al. [19]	Urban resilience and tourism economy in the Yangtze River Delta	Economic resilience indicators include GDP, fiscal expenditure, disposable income, tertiary-industry share, and science/technology expenditure	No
Zhao et al. [20]	Urban-resilience evaluation in the Yichang–Jingzhou–Jingmen–Enshi urban agglomeration	Economic indicators appear among the factors used to explain or evaluate urban resilience	Not a two-system coupling study
Guo et al. [21]	Urban resilience and low-carbon development in the Central Plains Urban Agglomeration	The resilience side is evaluated as a multidimensional urban system while the paired system also captures development transformation	No

The term “baseline specification” refers to the 17-indicator resilience and 9-indicator economic specification evaluated as Model A in this study; it does not denote an external model. The project-specific audit then screened the baseline specification for economic concepts appearing in both the resilience and economic-development systems. The audit identified GDP per capita, GDP scale, fiscal revenue, urban disposable income, fixed-asset investment, and retail sales as duplicated or conceptually duplicated variables. Entropy weights were recomputed after constant-price conversion for the baseline indicator blocks, and the total weight assigned to overlapping economic concepts was calculated for each construct. Table 2 reports the concept-level overlap counts, weight shares, and nested model sequence. This audit tests whether the apparent relationship between resilience and economic development is partly produced by measurement design.

The audit is not a rhetorical exercise; it is a formal measurement test. If overlapping variables receive meaningful weights, then the baseline resilience-economic relationship is partly mechanical. The main manuscript, therefore, reports both the overlap weight shares and the correlation between the baseline resilience and economic proxies. The paper is not presented as the first coupling study of Hebei, but as a demonstration that the conventional coupling approach can be misleading when construct overlap is not checked.

The nested analysis uses four models. Model A retains the complete baseline indices. Model B removes only the seven resilience-side overlap columns, keeps the Model A economic index fixed, and divides the retained resilience weights by their 0.555654 sum (renormalization factor 1.799682). Model C replaces Model B’s reduced resilience block with the final eight-indicator measured-capacity construct while keeping the Model A economic index fixed. Model D uses both final separated constructs. The Model A covar-

iance is also decomposed into shared-resilience $\times$ shared-economic, shared-resilience $\times$ remaining-economic, remaining-resilience $\times$ shared-economic, and remaining-resilience $\times$ remaining-economic blocks while retaining the full-index weights.

Table 2. Baseline overlap audit and nested correlation decomposition.

Overlapping Concept	Resilience-Side Count	Economic-Side Count	Baseline Resilience Weight Share	Baseline Economic Weight Share
GDP per capita	1	1	0.070	0.125
GDP scale	1	1	0.092	0.163
Fiscal revenue	1	1	0.075	0.132
Urban disposable income	2	1	0.060	0.053
Fixed-asset investment	1	1	0.066	0.118
Retail sales	1	2	0.082	0.290
Total overlapping economic concepts	7	7	0.444	0.882
Panel B. Nested model sequence				
Model	Measured-capacity/resilience specification	Economic specification	Weight treatment	Pearson r (all years; 2023)
A	Complete 17-indicator baseline index	Complete 9-indicator baseline index	Entropy weights within full indices	0.953; 0.973
B	A minus 7 resilience-side overlap columns	Model A unchanged	Retained A weights $\div$ 0.555654	0.783; 0.864
C	Final 8-indicator measured-capacity index	Model A unchanged	Final capacity weights sum to 1	0.293; 0.351
D	Final 8-indicator measured-capacity index	Final 6-indicator constant-price index	Weights sum to 1 within each construct	0.562; 0.679

The final measurement system follows one rule: no indicator can appear in both constructs. Ambiguous variables are assigned to one construct only. The construct logic is deliberately conservative. Economic variables are treated as resources, outcomes, or development conditions; public-service, infrastructure, utility, and ecological-service variables are treated as measured non-economic capacity; and R&D, FDI, and urbanization are treated only as contextual covariates. The resulting index is therefore not a complete measure of urban resilience. Because consistent city-year series were unavailable, it also excludes governance, social capital, emergency response, hazard exposure, social vulnerability, and institutional adaptation. It is a measured non-economic resilience-capacity index focused on observable city-level service, infrastructure, utility, and ecological-service capacity. The index intentionally excludes GDP, per capita GDP, fiscal revenue, household income, fixed-asset investment, employee wages, retail sales, and sectoral industrial-structure variables. The inclusion of green-space and utility indicators is consistent with research linking green infrastructure, ecosystem services, and energy systems to urban resilience [11,32,33]. The economic-development index measures economic capacity and household-market conditions through GDP, fiscal, income, wage, retail, and investment indicators. Table 3 reports the final non-overlapping indicator system and the entropy and equal-weight alternatives used in the robustness analysis.

Table 3. Final non-overlapping indicator system and weights.

Construct	Indicator	Unit	Entropy Weight	Equal Weight
Measured non-economic resilience capacity	Hospital beds per 10,000 residents	beds per 10,000 residents	0.081	0.125
Measured non-economic resilience capacity	Sewage treatment rate	percent	0.027	0.125
Measured non-economic resilience capacity	Harmless waste treatment rate	percent	0.030	0.125
Measured non-economic resilience capacity	Built-up area green coverage	percent	0.057	0.125
Measured non-economic resilience capacity	Park and green area per 10,000 residents	km ² per 10,000 residents	0.076	0.125
Measured non-economic resilience capacity	Electricity consumption per resident	kWh per resident	0.100	0.125
Measured non-economic resilience capacity	Urban gas supply per resident	m ³ per resident	0.500	0.125
Measured non-economic resilience capacity	Road area per resident	m ² per resident	0.130	0.125
Economic development	GDP per capita	yuan per resident	0.242	0.167
Economic development	Public-budget revenue per resident	yuan per resident	0.146	0.167
Economic development	Urban disposable income per capita	yuan per resident	0.103	0.167
Economic development	Average employee wage	yuan	0.115	0.167
Economic development	Retail sales per resident	yuan per resident	0.234	0.167
Economic development	Fixed-asset investment per resident	yuan per resident	0.160	0.167

Entropy weighting assigns half of the resilience-capacity weight to urban gas supply because this indicator has the largest dispersion over the city-year panel. The 0.500 share is a result of cross-observation dispersion, not a normative judgment that gas constitutes half of urban resilience. This makes the entropy-weighted index deliberately transparent but also vulnerable to single-indicator dominance. For that reason, the manuscript treats the entropy result as the primary objective-weighting estimate but accepts city conclusions only after robustness and stability checks. The gas indicator is not interpreted as a pure resilience asset; it may also reflect demand, heating systems, urban form, or industrial structure. The no-gas specification is therefore a binding sensitivity test rather than an optional appendix. Economic-development weights are more evenly distributed, ranging from 0.103 for urban disposable income to 0.242 for GDP per capita.

2.3. Index Construction, Mismatch Metrics, and Diagnostic Tests

All indicators are positive-direction variables. Let x_{itj} denote city i , year t , and indicator j . The primary analysis uses global min-max normalization over the full 2014–2023 panel:

$$x'_{(itj)} = (x_{(itj)} - \min(x_j)) / (\max(x_j) - \min(x_j)) \quad (1)$$

Global normalization preserves temporal change because each city-year observation is compared with the full panel range. This is appropriate for asking whether measured resilience capacity and economic development increased over the decade. Yearwise normalization is used as a sensitivity check because it compares cities only within the

same year. A 5th–95th percentile winsorized normalization is also estimated to test whether the mismatch pattern is driven by extreme indicator values.

Entropy weights are used as the primary objective-weighting method [34]. For each normalized indicator, proportions are calculated as:

$$p_{(itj)} = x'_{(itj)} / (\sum_{(i,t)} x'_{(itj)}) \quad (2)$$

The entropy value is:

$$e_j = -(1/\ln n) \sum_{(i,t)} p_{(itj)} \ln p_{(itj)} \quad (3)$$

and the weight is:

$$w_j = (1 - e_j) / (\sum_j (1 - e_j)) \quad (4)$$

The resilience and economic indices are weighted sums of their normalized indicators. Equal-weight indices are calculated from the same normalized variables to test whether rankings and mismatch conclusions depend on entropy weighting. Because urban gas supply receives a high entropy weight, the analysis also estimates a no-gas resilience specification and eight leave-one-resilience-indicator-out specifications. A deterministic multiverse additionally varies indicator selection (the baseline plus each of 14 one-indicator omissions), normalization (global min–max, yearwise min–max, or global 5th–95th percentile winsorized min–max), weighting (entropy or equal), and aggregation (weighted arithmetic or weighted geometric mean), yielding 180 specifications. For geometric aggregation, normalized values are mapped to $0.01 + 0.99x$ to avoid $\log(0)$. The main diagnostic outcome is not a coupling-coordination degree but a standardized mismatch score:

$$Mismatch_{it} = z(Economicindex_{it}) - z(Measurednon - economicresilience - capacityindex_{it}) \quad (5)$$

Positive values indicate that economic development is ahead of measured non-economic resilience capacity in standardized panel position. Negative values indicate that measured non-economic resilience capacity is stronger relative to the city's economic position. The mismatch score is, therefore, a relative diagnostic, not a direct growth-rate measure. This formulation is more interpretable than a generic coordination score because it preserves direction: it distinguishes cities whose economic position is stronger than their measured-capacity position from cities whose measured-capacity position is relatively stronger than their economic level. A separate within-year percentile-rank difference, $\text{rank}(\text{economy}) - \text{rank}(\text{measured capacity})$, checks whether directional conclusions depend on the z-score scale.

For 2023, cities are also classified into a fourfold typology using year-specific medians: high economy-high measured capacity, high economy-low measured capacity, low economy-high measured capacity, and low economy-low measured capacity. Although both procedures use the same economic and measured-capacity indices, they classify different properties. The panel-standardized mismatch direction indicates which standardized score is relatively higher, without classifying either score as high or low; the 2023 median typology indicates whether each score is above or below its 2023 median, without determining which score is ahead. Consequently, a high–high city may still be either economy-ahead or capacity-ahead. The typology is descriptive; it is not a normative ranking of cities. To avoid treating one index specification as definitive, 2023 city stability is evaluated across 13 specifications: the primary entropy index, equal weights, yearwise normalization, no-gas resilience, winsorized normalization, and eight leave-one-out resilience specifications. For each city, the analysis records whether the mismatch direction is stable and how often the city remains among the four highest economy-ahead cases. Table 4 reports both the level quadrant and mismatch direction and flags

specification-contingent classifications. Spatial diagnostics use a prefecture-level boundary layer and two row-standardized weight matrices: queen contiguity and 3-nearest-neighbor centroid weights. Global Moran's I is calculated for the 2023 economic index, measured non-economic resilience-capacity index, and mismatch score with 999 random permutations [35,36]. These tests assess spatial autocorrelation only; they are not interpreted as spillover models. The study, therefore, does not fit spatial regression, local-cluster, or spillover models because analysis of only 11 cities would create more inferential precision than the design can support.

Table 4. City-level mismatch, 2023 level quadrant, and robustness flag.

City	Economic 2023	Measured Capacity 2023	Z-Mismatch 2023	Rank Gap 2023	Economic Change	Capacity Change	2023 Level Quadrant	Robustness Flag
Tangshan	0.884	0.383	1.367	0.000	0.389	0.091	High-high	Gas-sensitive (11/13)
Langfang	0.660	0.286	1.236	0.182	0.264	−0.421	High-high	Stable economy-ahead (13/13)
Shijiazhuang	0.621	0.287	1.017	0.000	0.236	0.151	High-high	Stable economy-ahead (13/13)
Cangzhou	0.470	0.227	0.875	0.455	0.283	0.069	High-low	Mostly economy-ahead (11/13)
Baoding	0.262	0.196	0.096	0.091	0.213	−0.036	Low-low	Specification -sensitive (9/13)
Hengshui	0.303	0.227	−0.017	0.091	0.253	0.095	Low-low	Specification -sensitive; rank reversal
Chengde	0.398	0.285	−0.153	−0.091	0.254	0.152	High-high	Specification -sensitive (9/13)
Handan	0.352	0.263	−0.159	−0.091	0.249	0.036	Low-high	Mostly capacity-ahead (12/13)
Zhangjiakou	0.329	0.259	−0.231	0.000	0.234	0.142	Low-low	Mostly capacity-ahead (12/13)
Xingtai	0.243	0.262	−0.731	−0.364	0.232	0.085	Low-low	Stable capacity-ahead (13/13)
Qinhuangdao	0.435	0.369	−0.874	−0.273	0.173	0.155	High-high	Stable capacity-

	ahead (13/13)
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Two-way fixed-effects models were used only as internal descriptive association checks rather than causal tests. They included city and year fixed effects and city-clustered standard errors, but the small number of city clusters means that *p*-values should be treated cautiously. These checks were used only to guard against an automatic-conversion interpretation; they are not treated as standalone evidence.

Obstacle diagnostics translate the index result into city-specific capacity shortfalls. For each city in 2023, the shortfall for the measured resilience-capacity indicator *j* is $1 - x'_{ij}$. Entropy weights construct the index by emphasizing cross-observation information; the obstacle diagnostic instead assigns equal contributions so that the gas indicator cannot dominate the shortfall narrative. The obstacle shares are, therefore, not an additive decomposition of the entropy-weighted index. Equal-weight obstacle shares are reported because entropy-weighted obstacle shares would be dominated by the high gas-supply weight. The top three obstacle indicators by Hebei city are reported in Supplementary Table S2.

3. Results

3.1. Nested Audit Separates Overlap Removal from Construct Redesign

The overlap audit identifies seven economic indicators or economic concepts appearing in both the baseline resilience and economic systems. These overlapping concepts account for 44.4% of the baseline resilience-index entropy weight and 88.2% of the baseline economic-index entropy weight. Retail sales, GDP scale, fixed-asset investment, fiscal revenue, and GDP per capita together dominate the baseline economic index and also enter the resilience side. Under this construction, the baseline resilience and economic proxies have a Pearson correlation of 0.953 over all city-years and 0.973 in 2023. These values establish substantial overlap risk but do not by themselves isolate the effect of duplication.

This result is not evidence that Hebei’s resilience and economic development were strongly coordinated. It indicates substantial mechanical exposure in the baseline design, but the nested sequence is needed to isolate overlap removal from subsequent redesign. Model B, which removes only the shared resilience-side components and renormalizes the retained weights, lowers the all-year correlation from 0.953 to 0.783 and the 2023 correlation from 0.973 to 0.864. The all-year decline of 0.170 is 43.5% of the net Model A-to-Model D decline. Model C, which introduces the final measured-capacity construct while retaining the baseline economic index, has correlations of 0.293 over all years and 0.351 in 2023; Model D, using both final constructs, has correlations of 0.562 and 0.679. Thus, the original two-model difference cannot be attributed solely to overlap removal; construct redefinition, indicator replacement, and economic-index redesign also matter.

The overlap audit changes the paper’s scientific status. The targeted literature audit shows that economic content inside resilience systems is not unusual in recent Chinese coupling studies, but the weight share of that overlap is rarely made explicit before coordination is interpreted. The Hebei case, therefore, functions as a worked measurement test: it separates the effect of overlap-only removal from subsequent construct and indicator redesign.

The covariance decomposition provides complementary evidence. Of the total Model A covariance (0.0316), the shared-resilience × shared-economic block contributes 56.0%, shared-resilience × remaining-economic 3.5%, remaining-resilience × shared-economic 39.2%, and remaining-resilience × remaining-economic 1.3%. The shared-shared

contribution confirms mechanical exposure, while the remaining blocks show why duplication cannot be treated as the sole explanation for the baseline correlation.

3.2. The Final Panel Shows Uneven Indicator Variation

The final panel contains 110 complete city-year observations. The measured non-economic resilience-capacity indicators show very different levels of dispersion. Hospital beds average 56.8 per 10,000 residents; road area averages 23.5 m² per resident; electricity consumption averages 4955 kWh per resident; and gas supply averages 102.5 m³ per resident. Ecological-service indicators show ceiling effects: the harmless waste treatment rate is essentially 100% throughout the panel, and sewage treatment averages 98.4%. These ceiling effects explain their low entropy weights. They remain in the index because they are conceptually relevant, but they contribute little to cross-city differentiation.

Constant-price economic indicators show broader temporal and cross-city variation. GDP per capita ranges from 25,066 to 102,073 yuan in 2014 prices. Public-budget revenue per resident ranges from 1319 to 7167 constant yuan, retail sales per resident range from 10,973 to 32,415 constant yuan, and fixed-asset investment per resident ranges from 18,310 to 102,963 constant yuan. The resulting economic index spans 0.011 to 0.884, compared with 0.117 to 0.707 for the measured non-economic resilience-capacity index. Full descriptive statistics are reported in Supplementary Table S3. The stronger variation in the economic indicators partly explains why the economic index shows a steeper temporal rise than the resilience index.

These descriptive results also clarify why the study avoids causal language. The indices are useful summaries of city-level capacity, but they compress heterogeneous dimensions. A high resilience-capacity score may reflect infrastructure and utility variation more than ecological variation, especially under entropy weighting. A high economic score may reflect per capita GDP and investment more than household welfare. Section 3, therefore, interprets index movement as a diagnostic pattern, not as a causal mechanism.

3.3. Economic Development Increased Faster than Measured Non-Economic Resilience Capacity

The entropy-weighted constant-price economic index rose from a mean of 0.198 in 2014 to 0.451 in 2023. The measured non-economic resilience-capacity index rose from 0.230 to 0.277 over the same period. The mismatch mean shifted from −0.610 in 2014 to 0.220 in 2023. Figure 1 maps the 2023 mismatch pattern, while Figure 2 shows the decade-long divergence between the economic and measured non-economic resilience-capacity indices. This does not mean all cities became economy-ahead; rather, it means that the panel-wide center of gravity moved toward a stronger economic position relative to measured non-economic resilience capacity.

The annual trajectory is not monotonic in every year. The constant-price Hebei economic index increased rapidly between 2014 and 2018, softened slightly in 2019, and then rose again through 2023. The Hebei resilience-capacity index was nearly flat between 2014 and 2019 and improved more clearly after 2020. Full Hebei annual mean values are reported in Supplementary Table S4; Figure 2 carries the main-text trend evidence. This pattern is consistent with gradual infrastructure and service-capacity accumulation, but the improvement was not fast enough to match the economic index's rise.

Two features of the annual series deserve emphasis. First, economic dispersion increases over time, with the standard deviation rising from 0.164 to 0.197. This suggests that Hebei's city economies were not converging in the index space. Second, resilience-capacity dispersion declines sharply from 0.167 in 2014 to around 0.057 in 2023. This suggests that measured non-economic capacities became more similar across cities, but at

a relatively modest level. The combination of widening economic differences and converging but slowly improving resilience capacity is central to the mismatch diagnosis.

Economic-Measured-Capacity Mismatch Across Hebei Cities, 2023

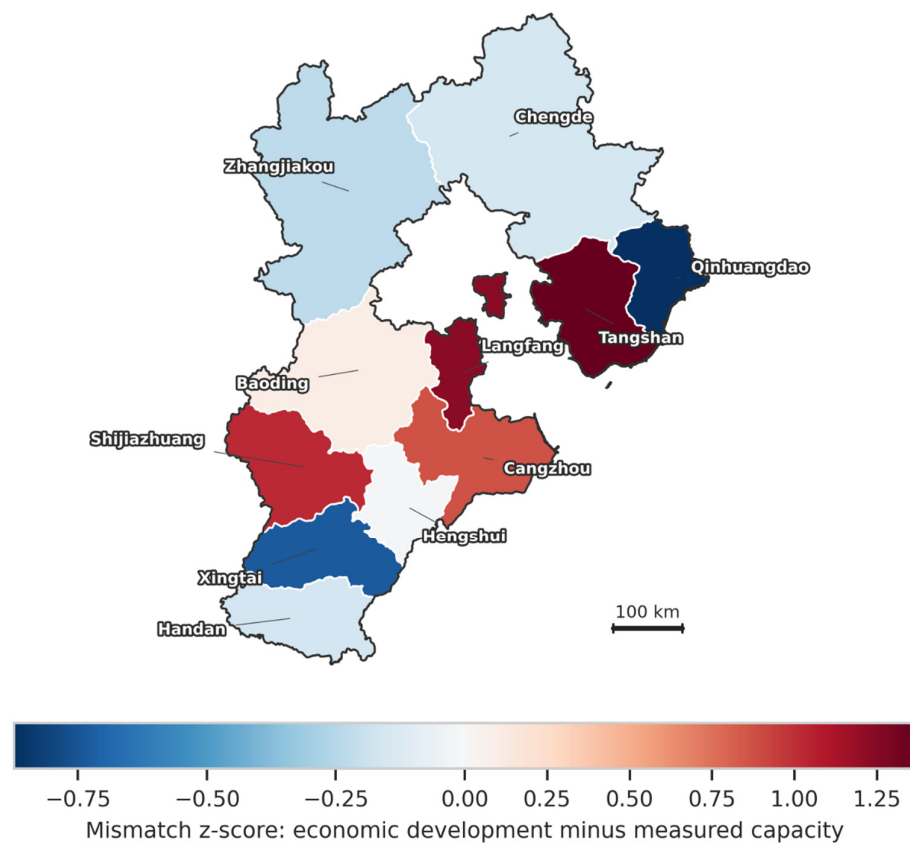


Figure 1. Hebei city economic-measured-capacity mismatch in 2023.

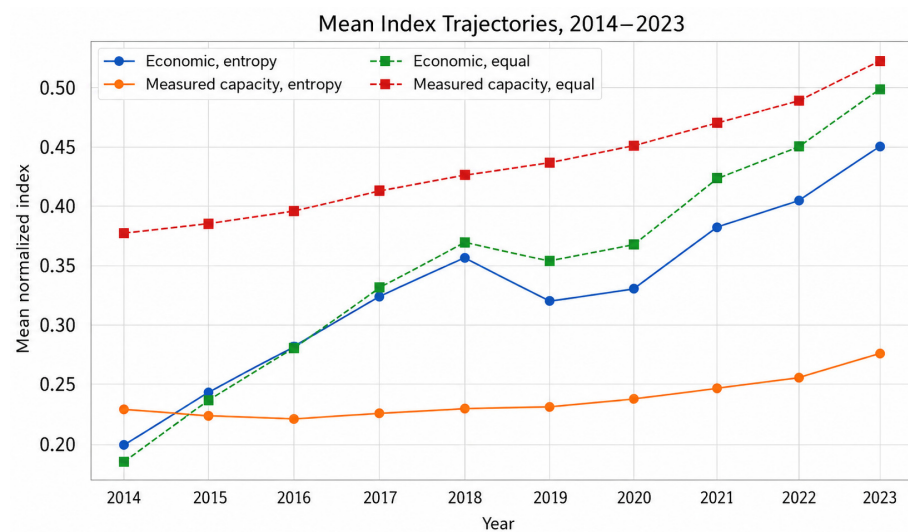


Figure 2. Mean economic and measured non-economic resilience-capacity index trajectories, 2014–2023.

Descriptive Temporal Heterogeneity Around 2020

The annual mean slope of measured capacity is 0.0008 per year in 2014–2019 and 0.0127 in 2020–2023; the corresponding constant-price economic slopes are 0.0283 and 0.0383. The mismatch slopes are 0.1428 and 0.0650. These descriptive differences contextualize the period spanning the COVID-19 shock and early recovery, but four post-2020 observations, no comparison province, and overlapping policy changes preclude a causal or formal structural-break interpretation.

3.4. City-Level Mismatch in 2023

In 2023, Tangshan has the highest economic development score (0.884) and the highest positive mismatch score in the primary entropy specification (1.367). Langfang (1.236), Shijiazhuang (1.017), and Cangzhou (0.875) also show strong economy-ahead mismatch. Qinhuangdao has the most negative mismatch score (−0.874), and Xingtai is also negative (−0.731). These values mean that the primary specification identifies Tangshan, Langfang, Shijiazhuang, and Cangzhou as more economically advanced than their measured non-economic resilience scores would suggest, while Qinhuangdao and Xingtai have resilience scores that are stronger relative to their economic scores.

The 2023 median typology provides a level classification distinct from the panel-standardized mismatch direction. Table 4 reports the 2023 city scores, decade changes, and median-based typology. Figure 3 displays the city mismatch scores, and Figure 4 shows how the typology depends on each city's joint economic and measured-capacity position. Tangshan, Langfang, Shijiazhuang, Chengde, and Qinhuangdao are above the 2023 medians for both economy and measured resilience capacity, although Tangshan, Langfang, and Shijiazhuang still have positive economy-ahead mismatch. Cangzhou is the only high-economy-low-capacity city because it combines a high economic score with a below-median measured resilience-capacity score. Baoding, Hengshui, Zhangjiakou, and Xingtai are low–low in median terms. Handan falls in the low-economy-high-capacity quadrant because its measured resilience-capacity score is above the median while its economic score is below the median.

The change columns show that economic development increased in every city, but resilience did not. Langfang's negative resilience change is especially large and is partly driven by its high baseline value in the normalized resilience index. This should be interpreted as a source-sensitive diagnostic rather than a claim that all underlying resilience services deteriorated uniformly. Still, the result is substantively important: when a city begins the panel with unusually high normalized infrastructure-service values, later economic gains can produce a large economy-ahead mismatch even if the city remains above the median in 2023.

The stability checks sharpen the primary ranking. Table 5 reports the 13-specification stability summary used to separate robust city findings from specification-sensitive ones. Langfang and Shijiazhuang keep the same economy-ahead direction in all 13 specifications. Cangzhou does so in 11 of 13 and remains among the four highest economy-ahead cases in all 13. Table 4 flags each city as stable, mostly stable, gas-sensitive, or specification-sensitive. Tangshan remains a top-four economy-ahead case in 11 of 13 specifications, but it changes direction when gas supply is removed; its primary ranking is therefore partly gas-sensitive. Qinhuangdao and Xingtai keep a resilience-ahead direction in all 13 specifications. The middle cities are less stable: Baoding remains economy-ahead but usually below the top four, while Hengshui, Handan, Chengde, and Zhangjiakou change direction under some specifications. The revised interpretation is, therefore, not a simple ranking; it is a distinction between robust mismatch, measurement-sensitive mismatch, and unstable middle cases.

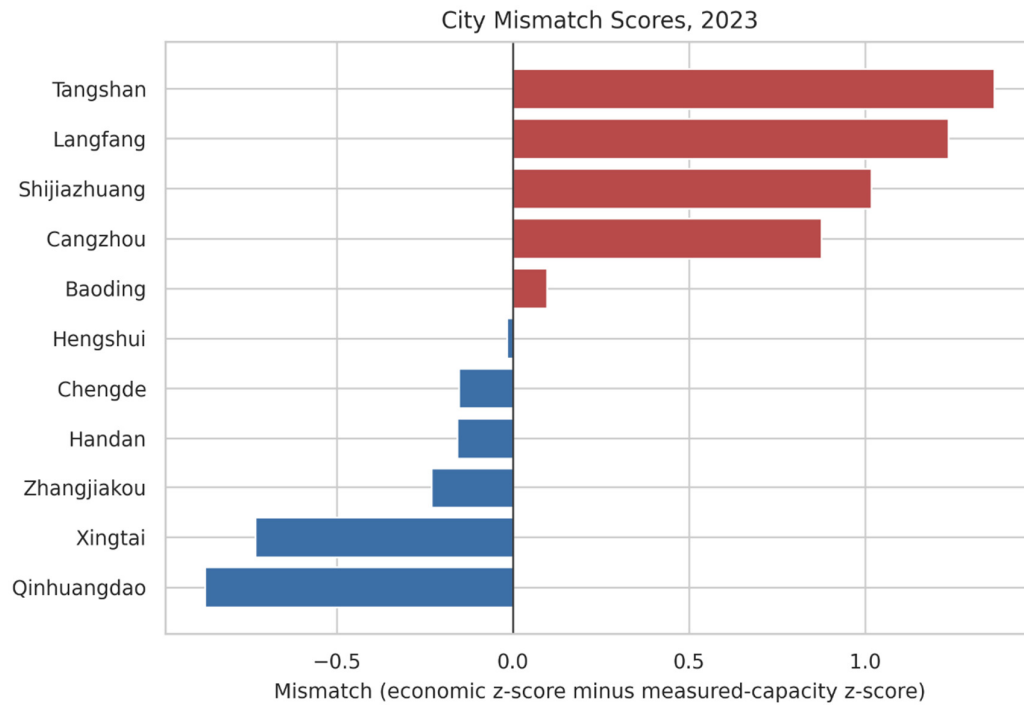


Figure 3. City mismatch scores in 2023.

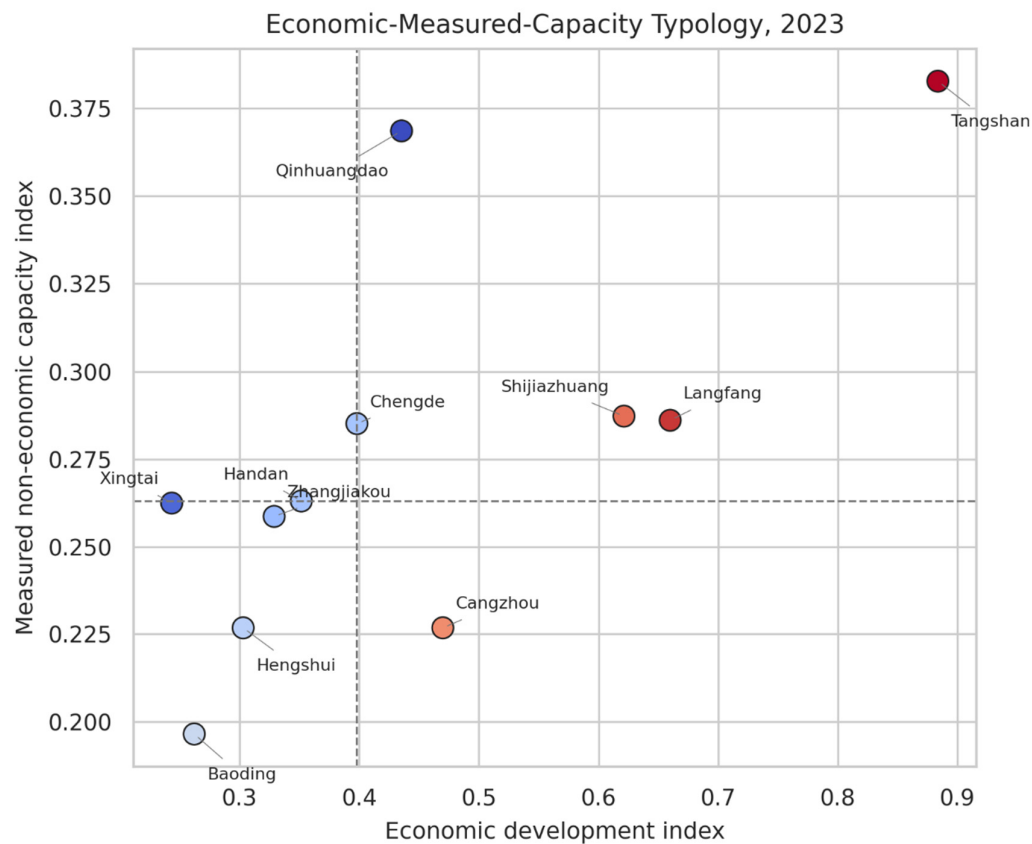


Figure 4. Economic-measured-capacity typology scatterplot, 2023.

The 2023 within-year rank-gap metric agrees with the z-score direction for seven cities, yields ties for Tangshan, Shijiazhuang, and Zhangjiakou, and reverses only Hengshui. Across the 180 multiverse specifications, the 2023 economic-capacity correlation has a median of 0.605 and ranges from 0.217 to 0.873; the mismatch-ranking correlation with the primary specification has a median Spearman coefficient of 0.845 and ranges from 0.309 to 1.000. Economy-ahead shares are 99.4% for Shijiazhuang, 90.0% for Langfang, 88.3% for Cangzhou, and 66.1% for gas-sensitive Tangshan, compared with 0.0% for Xingtai, 4.4% for Handan, and 10.0% for Qinhuangdao.

Table 5. City stability across 13 selected specifications and the 180-specification multiverse, 2023.

City	Baseline Direction	Same Direction Count	Top-Four Economy-Ahead Count	Economy-Ahead Share (180 Specs)	Interpretation
Tangshan	Economy-ahead	11/13	11/13	66.1%	High but gas-sensitive
Langfang	Economy-ahead	13/13	12/13	90.0%	Stable economy-ahead
Shijiazhuang	Economy-ahead	13/13	13/13	99.4%	Stable economy-ahead
Cangzhou	Economy-ahead	11/13	13/13	88.3%	Mostly economy-ahead
Baoding	Economy-ahead	9/13	2/13	75.6%	Specification-sensitive
Hengshui	Capacity-ahead	8/13	1/13	53.9%	Highly contingent
Chengde	Capacity-ahead	9/13	0/13	23.9%	Specification-sensitive
Handan	Capacity-ahead	12/13	0/13	4.4%	Mostly capacity-ahead
Zhangjiakou	Capacity-ahead	12/13	0/13	15.0%	Mostly capacity-ahead
Xingtai	Capacity-ahead	13/13	0/13	0.0%	Stable capacity-ahead
Qinhuangdao	Capacity-ahead	13/13	0/13	10.0%	Stable capacity-ahead

3.5. Spatial Diagnostics

The spatial diagnostics show that measured non-economic resilience capacity has detectable global autocorrelation under queen contiguity in 2023, while economic development and mismatch show no statistically detectable global autocorrelation under the tested specifications. Table 6 reports the Moran diagnostics and the index-level robustness correlations. Under queen contiguity, the resilience Moran's I is 0.508 with a permutation p -value of 0.025. Under 3-nearest-neighbor weights, resilience Moran's I remains positive at 0.379, with $p = 0.058$. Economic development has weakly negative Moran's I values under both matrices, and mismatch shows no statistically detectable global autocorrelation under the tested specifications.

Table 6. Spatial and index-level robustness diagnostics.

Diagnostic	Specification	Statistic	p -Value or Rank Statistic
Economic Moran's I	Queen contiguity	−0.075	0.802
Measured-capacity Moran's I	Queen contiguity	0.508	0.025
Mismatch Moran's I	Queen contiguity	−0.132	0.666
Economic Moran's I	3-nearest neighbors	−0.006	0.989
Measured-capacity Moran's I	3-nearest neighbors	0.379	0.058
Mismatch Moran's I	3-nearest neighbors	−0.099	0.682
Mismatch robustness	Entropy versus equal weights	Pearson 0.913	Spearman 0.955
Mismatch robustness	Global versus yearwise normalization	Pearson 0.815	Spearman 0.836
Mismatch robustness	Primary versus no-gas specification	Pearson 0.834	Spearman 0.827
Mismatch robustness	Primary versus winsorized normalization	Pearson 0.895	Spearman 0.909
Mismatch robustness	Leave-one-capacity-indicator-out minimum	Pearson 0.834	Spearman 0.827
Rank-gap direction	Within-year percentile ranks	7 same; 3 ties	1 opposite
Multiverse economic-capacity correlation	180 specifications	Median 0.605	Range 0.217–0.873
Multiverse mismatch-rank stability	Versus primary specification	Median Spearman 0.845	Range 0.309–1.000

The spatial result matters because it separates two policy logics. Measured resilience capacity appears to have a regional geography, which may reflect shared infrastructure systems, ecological zones, city-size gradients, and neighboring administrative contexts. Mismatch shows no statistically detectable global autocorrelation under the tested specifications; this does not establish that geography is absent. The test, therefore, does not support a single contiguous global clustering pattern. The robustness rows also show why the city interpretation must be stability-based: the 2023 mismatch ranking remains strongly related to the primary ranking under equal weights, yearwise normalization, winsorized normalization, and the no-gas specification, but the no-gas test is the binding stress test and exposes Tangshan's sensitivity to the utility proxy.

3.6. Descriptive Fixed-Effects Check

A descriptive fixed-effects screen was used as a guardrail against overstatement. It did not provide evidence that within-city economic development automatically translates into measured non-economic resilience capacity after city and year effects are included. With only 11 city clusters, its *p*-values are fragile and are not used to identify mechanisms. The main evidentiary basis for the manuscript is therefore the construct-overlap audit, the separated indices, the city mismatch/stability diagnostics, spatial autocorrelation tests, and obstacle analysis, not the fixed-effects coefficients.

3.7. Obstacle Factors

Obstacle diagnostics show that infrastructure indicators are the most common resilience shortfalls in 2023. Because the obstacle analysis is a separate equal-contribution diagnostic, these shares should not be read as an additive decomposition of the entropy-weighted index. Figure 5 displays the equal-weighted obstacle shares by city, and Figure 6 shows the weighting robustness of the mismatch scores. Gas supply and road area appear repeatedly among the top obstacles. Park green area and green coverage are also important in Cangzhou, Langfang, Shijiazhuang, Tangshan, Zhangjiakou, Chengde, Handan, and Qinhuangdao. Electricity appears among the top obstacles in Baoding, Hengshui, and Xingtai. These obstacle patterns identify relative utility, transport, and green-service shortfalls; they are not evidence of a causal conversion failure.

For Tangshan, the obstacle analysis suggests that a high economic score coexists with infrastructure and green-coverage shortfalls relative to the panel maximum, but this interpretation is conditional on the utility proxy because Tangshan is gas-sensitive. For Cangzhou, the concern is stronger because the city is economy-ahead while its resilience score is below the 2023 median. For Shijiazhuang and Langfang, the result points to metropolitan-growth pressure: economic and population-related demand can exceed the relative position of measured road, gas, and green-space capacity. For Qinhuangdao, the negative mismatch does not eliminate policy needs; road area, gas supply, and green coverage remain among its main shortfalls. The obstacle results, therefore, provide a more operational inventory of relative shortfalls without identifying their causes.

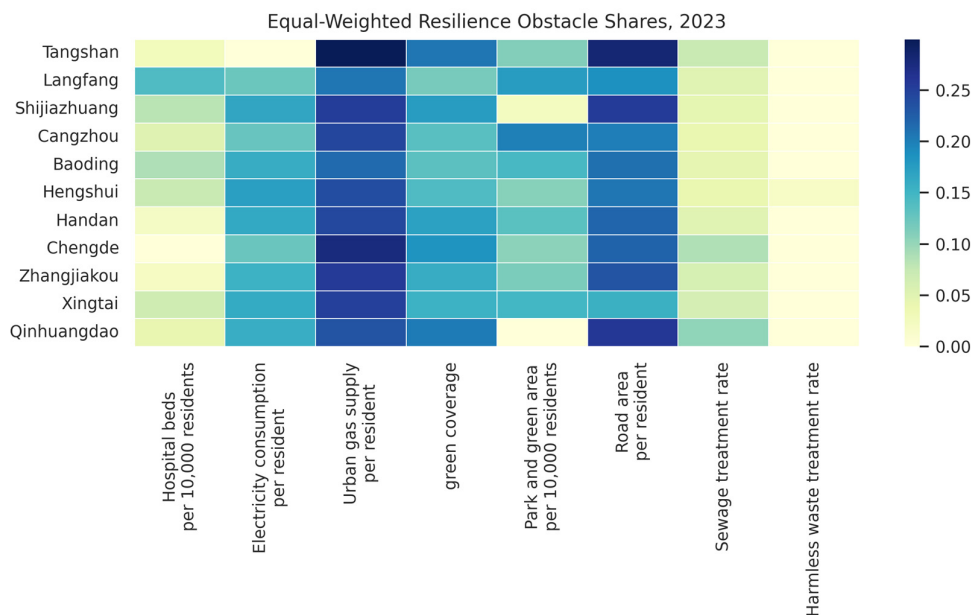


Figure 5. Equal-weighted resilience obstacle shares, 2023.

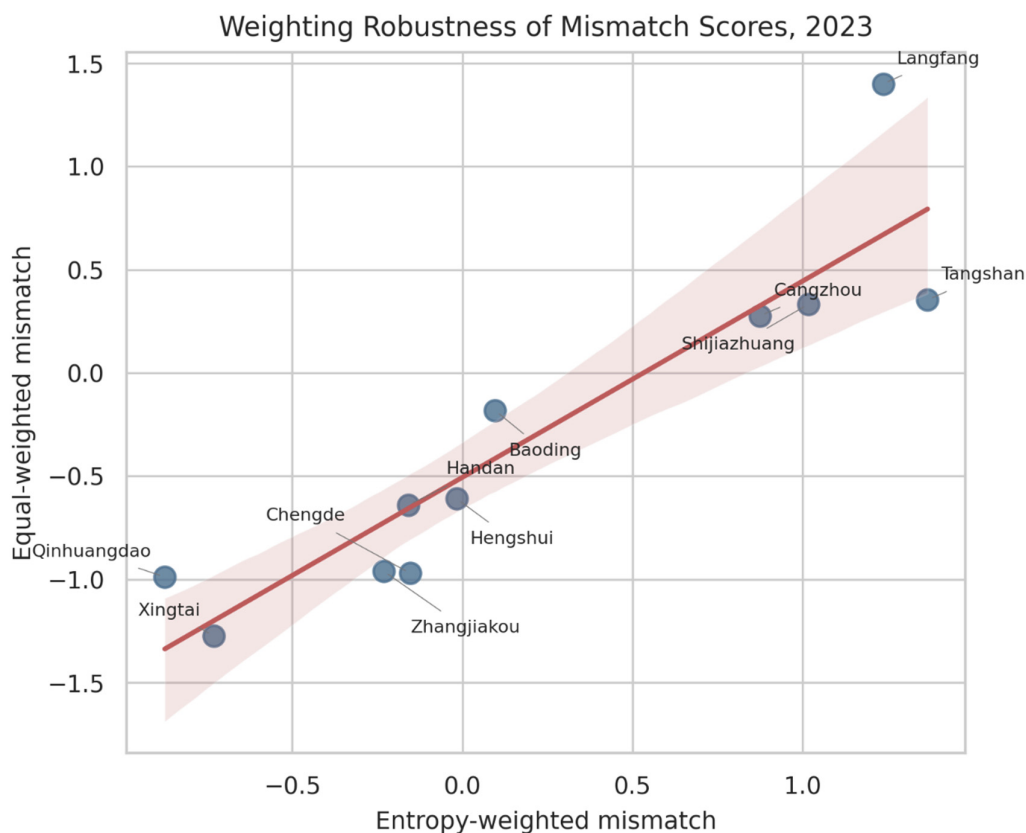


Figure 6. Weighting robustness of mismatch scores with uncertainty band, 2023.

4. Discussion

4.1. From Coupling Scores to Construct-Valid Mismatch

The central finding is methodological and substantive at the same time. It also defines the manuscript's boundary relative to the published Hebei industrial-structure study [21].

That article examined how sectoral structure and economic growth evolved in Hebei. The present study does not re-estimate industrial restructuring and does not ask whether Hebei's economy grew or upgraded. It asks whether an urban-resilience-development assessment remains meaningful after economic indicators are removed from the resilience construct. Methodologically, the baseline design would have treated economic development as both the explanatory system and a large part of the resilience system. The duplicated economic concepts account for 44.4% of the resilience-side entropy weight and 88.2% of the economic-side weight, producing an all-year resilience-development correlation of 0.953. The nested audit qualifies that interpretation: overlap-only removal lowers the all-year correlation to 0.783, which is 43.5% of the net decline to the final 0.562 correlation; construct redefinition and indicator redesign account for the remainder. The empirical question therefore shifts from whether two indices move together to where economic development and measured health-service, infrastructure, utility, and ecological-service capacity occupy different relative positions.

Converting monetary variables to constant 2014 prices has a modest effect on the overlap audit but a larger effect on the trend and middle-city classifications. The Model A-D correlations change from 0.948, 0.773, 0.290, and 0.535 under nominal prices to 0.953, 0.783, 0.293, and 0.562 under constant prices. Deflation reduces the decade increase in the economic mean from 0.351 to 0.253 (28.1%), preserves the economic rank order and the strongest positive and negative cases, and changes the mismatch sign for four middle cities; these middle cases are therefore interpreted cautiously.

This distinction matters because the Chinese coupling-coordination literature is now dense enough that another city-panel coupling score is unlikely to be persuasive by itself [12–20]. The contribution here is not priority of topic or geography. Studies have already examined resilience, urbanization, tourism, digital economy, eco-economic systems, sub-system coupling, low-carbon development, and Hebei's industrial-structure/economic-growth trajectory [13–24]. The targeted audit strengthens the paper's logic: the problem is not simply that one draft used overlapping indicators, but that economic variables are often placed inside resilience systems while the paired system also measures development transformation. The stronger claim is that a common research design can overstate coordination when the compared systems are not cleanly separated. Composite indicators are useful precisely because they condense multidimensional systems, but that condensation creates responsibility: before a coordination model is interpreted, the constructs must be shown to be distinct [25,26].

The revised analysis, therefore, reframes coordination as a relative-capacity diagnosis. Economic resources may enable resilience investments, but they do not themselves constitute measured service, infrastructure, utility, or ecological resilience capacity. A city can have high GDP per capita, strong fiscal revenue, high wages, and large investment while still lagging in road space, gas supply, medical-service capacity, green coverage, or ecological-service provision. Conversely, a city may appear economically modest while retaining relative service or ecological advantages. The mismatch score makes this direction visible. It identifies relative gaps in the measured indicators; neither the correlation decline nor the mismatch score establishes that economic development failed to convert into resilience capacity.

4.2. Hebei's Policy Geography: Relative-Capacity Diagnosis Rather than Coordination

Hebei is a useful setting because it is not a uniform provincial economy. It is a policy geography organized around the Beijing–Tianjin–Hebei coordinated development region, heavy-industrial transformation, port and coastal development, corridor growth, southern industrial cities, agricultural and transport cities, and northern ecological-fringe functions. A single “higher coordination is better” reading would flatten these differences. The

mismatch results instead show several development positions that require different interpretations.

Langfang and Shijiazhuang are not weak cities in absolute terms. Both are above the 2023 median on economic development and measured non-economic resilience capacity, yet they remain economy-ahead across all robustness specifications. Their positive mismatch indicates a relative pace imbalance, not an absence of measured capacity. For Langfang, the result is consistent with a Beijing–Tianjin corridor city whose economic and population-related demand can strain road space, utility provision, and green-service supply. For Shijiazhuang, the provincial-capital role creates a different demand profile: service concentration and administrative functions raise economic centrality, but measured infrastructure and green-service capacity do not occupy the same relative position. Tangshan has the highest primary mismatch score, but the no-gas test shows that its classification depends partly on the utility proxy. It should therefore be treated as a high-priority but measurement-sensitive case, not as a fully stable economy-ahead result.

Cangzhou is more concerning because it is the clearest 2023 economy-ahead city in the median typology. It combines a relatively high economic score with a below-median measured resilience-capacity score and remains a top-four economy-ahead case in all 13 specifications, although its direction is positive in 11 of 13. As a coastal and port-linked industrial city, its economic position can rise through logistics, manufacturing, and investment channels without guaranteeing equivalent improvement in road, utility, medical-service, or green-service indicators. That combination illustrates why construct overlap can inflate apparent alignment even when measured non-economic resilience capacity remains comparatively weak. The obstacle diagnostics point to green-service and infrastructure shortfalls rather than to a general absence of development. This makes Cangzhou a case where sustainable development policy should focus on the composition of investment, not only the level of economic activity.

Qinhuangdao illustrates the opposite pattern. Its negative mismatch reflects a resilience score that is relatively high compared with its economic position, plausibly consistent with coastal service functions, ecological amenities, and infrastructure characteristics captured by the index. Yet a resilience-ahead classification is not a declaration of comprehensive resilience. The obstacle analysis still identifies road area, gas supply, and green coverage as limiting factors. Xingtai also shows negative mismatch, but for a different reason: its economy score remains low, so the negative gap should not be read as overall strength. The northern ecological-fringe cities, Zhangjiakou and Chengde, require still another reading. Their regional role is tied to ecological services, mountain-region governance, and environmental coordination rather than to simply replicating the industrial or corridor-city growth path. These differences are exactly why a directional mismatch framework is more informative than a scalar coordination score.

4.3. *Why Growth Does Not Automatically Become Measured Resilience Capacity*

The descriptive association checks are useful mainly as a guardrail against overstatement. Once city and year effects are included, the association does not support an automatic-conversion story. This does not prove that economic growth is irrelevant; the model is not a causal design, and the number of city clusters is small. It does show that, in this panel, the decade's economic gains are not accompanied by a proportional within-city increase in the measured non-economic capacities.

This pattern is consistent with regional resilience theory, which distinguishes growth from adaptability and shock capacity [37–41]. Growth expands resources, but the path from resources to resilience is mediated by fiscal priorities, infrastructure planning, service delivery, land development, industrial structure, and environmental management. Some resilience capacities are stock variables that change slowly. Roads, utility networks,

medical facilities, and green infrastructure require capital allocation, spatial planning, operating capacity, and time. Other indicators have ceiling effects, such as waste and sewage treatment rates, so they cannot rise at the same pace as economic indicators even when services are maintained. A rapid rise in GDP, investment, wages, or retail activity can therefore widen mismatch if the public-service and infrastructure base moves more slowly.

These association checks should be read in this constrained way. Their purpose is not to identify whether R&D, FDI, or urbanization causes mismatch; the panel is too small and the design too observational for that claim. The more defensible conclusion is that economic dynamism has different sectoral and spatial channels, and only some of those channels are likely to improve measured non-economic resilience capacity.

4.4. Implications for Sustainable Regional Governance and Coupling Research

For policy, the practical implication is to treat mismatch as a screening signal for examining possible conversion channels, not as proof of conversion failure. Economy-ahead cities need to show how economic capacity becomes measured resilience capacity through specific channels: utility-network reliability and coverage, road-space adequacy, medical-service capacity, green-space provision, and the fiscal or project allocation that supports these systems. The most stable economy-ahead cases are Langfang and Shijiazhuang; Cangzhou is mostly stable; Tangshan warrants attention but also illustrates why utility-proxy sensitivity must be disclosed. The appropriate intervention is not the same in every city. For Langfang, corridor growth points toward transport, utility, and green-space capacity relative to metropolitan spillover demand. For Shijiazhuang, the priority is aligning provincial-capital service concentration with road, medical, and green-service capacity. For Cangzhou, the question is more basic: why measured resilience capacity remains below the median despite economic strength, and whether port-industrial growth is being matched by municipal utility, road, and ecological-service investment. In low-low cities, economic upgrading and measured-capacity investment should be planned together. In relative resilience-ahead cities, policy should protect existing advantages while addressing the specific obstacles rather than assuming that a favorable mismatch score means the city is resilient in all dimensions.

At the provincial scale, the spatial diagnostics argue for a two-level strategy. Measured non-economic resilience capacity shows detectable global autocorrelation under queen contiguity and a positive but not statistically detectable result under the 3-nearest-neighbor specification, suggesting that utility infrastructure, ecological services, and public-service capacity have regional structure. Mismatch shows no statistically detectable global autocorrelation under the tested specifications; this does not establish that geography is absent. Provincial policy should therefore coordinate regionally where systems are regional but diagnose mismatch city by city where the gap is local to a city's development trajectory.

For research, the study suggests three reporting norms for future coupling-coordination work. First, papers should report an overlap audit before estimating coupling or coordination. The audit should identify shared variables, shared concepts, and the weight share assigned to duplicated constructs; Table 1 shows that this risk can appear in otherwise policy-relevant studies. Second, the direction of imbalance should be reported alongside any scalar coordination measure. A high coordination score and a positive economy-ahead mismatch imply different policy stories. Third, robustness checks should be routine rather than optional. In this study, the 2023 mismatch ranking is stable across entropy and equal weights (Spearman 0.955), yearwise normalization (0.836), winsorized normalization (0.909), and the no-gas specification (0.827). The no-gas test changes Tangshan's classification, which is precisely why city-level stability should be reported rather than hidden

behind one map. Across the 180-specification multiverse, the primary mismatch ranking has a median Spearman correlation of 0.845, with a range of 0.309–1.000.

The spatial diagnostics also clarify what the study does not claim. A significant Moran's *I* for resilience supports a clustering description, not a spillover mechanism. A non-significant Moran's *I* for mismatch does not mean geography is irrelevant; it means that the directional gap is not well described by global spatial clustering at the prefecture-city scale. This distinction is important for sustainability research because maps can easily invite overinterpretation. Spatial statistics should discipline the map, not decorate it.

4.5. Limitations and Next Tests

The study has six main limitations. First, the literature audit is targeted rather than systematic; it identifies construct-overlap risk in close comparator studies but does not estimate the prevalence of the problem across the full field. Second, the analysis includes only 11 prefecture-level cities, which limits statistical power and transferability beyond Hebei; it is ecological and city-level. It cannot measure household resilience, neighborhood inequality, individual hazard exposure, or firm-level adaptive capacity. Third, the measured non-economic resilience-capacity index is necessarily narrower than the full theoretical concept of urban resilience. Governance capacity, social capital, emergency response, social vulnerability, digital infrastructure, climate exposure, institutional learning, and disaster-specific preparedness are not included because consistent city-year indicators were not available in the verified panel. Fourth, several indicators mix capacity and use. Electricity and gas per resident may reflect infrastructure availability, demand intensity, industrial structure, or climate and heating needs. They are relevant to utility capacity, but they should not be interpreted as pure resilience assets; the no-gas robustness test bounds this concern but does not eliminate it. Fifth, the study diagnoses mismatch but does not explain causal conversion mechanisms; the pre/post-2020 slopes are descriptive rather than a causal pandemic or structural-break test. Fiscal allocation, infrastructure-project timing, land-development decisions, utility-network investment, and governance capacity are plausible channels, but they are not measured directly in the present panel. Sixth, the spatial analysis reports global autocorrelation only. With 11 cities, more complex spatial panel models would create a false sense of precision unless supported by stronger design or more geographic units.

These limitations define the next research agenda. A stronger causal study would need policy timing, infrastructure-project data, fiscal-allocation records, or quasi-experimental variation. A stronger resilience study would add hazard exposure, emergency-management capacity, social vulnerability, and service accessibility. A stronger spatial study would test local clusters, alternative zoning, and cross-boundary infrastructure systems. The present paper makes a narrower but necessary contribution: it shows that, for Hebei's city system, the sustainability question is not whether economic development and resilience can be made to produce a high coupling score. It is where economic development and the measured non-economic capacities that support urban resilience occupy different relative positions.

5. Conclusions

This study revised a conventional urban-resilience-economic development coupling problem into a construct-valid mismatch analysis. It did not ask the same question as prior Hebei industrial-structure and economic-growth research; it tested whether resilience-development assessment remains interpretable after the two constructs are separated. The targeted literature audit shows that economic content is commonly embedded in urban-resilience systems without an explicit construct-overlap weight test. The Hebei audit then shows why this matters empirically: duplicated economic concepts account for 44.4% of

the resilience-side weight and 88.2% of the economic-side weight, producing a resilience-development correlation of 0.953. Removing only the resilience-side overlap lowers the correlation to 0.783, accounting for 43.5% of the net decline to the final separated correlation of 0.562; construct redefinition and indicator redesign also materially affect the comparison.

From 2014 to 2023, Hebei's constant-price economic-development index increased much faster than its measured non-economic resilience-capacity index. In 2023, Langfang and Shijiazhuang were stable economy-ahead cases, while Cangzhou was mostly economy-ahead; Tangshan is high in the primary model but sensitive to the gas-supply proxy; and Qinhuangdao and Xingtai show stable measured-capacity-ahead directions. Spatial diagnostics detect global autocorrelation in measured non-economic resilience capacity under queen contiguity, while mismatch shows no statistically detectable global autocorrelation under the tested specifications. These findings support regional attention to measured capacity and city-specific follow-up of mismatch without establishing a spatial spill-over mechanism. Obstacle diagnostics point especially to infrastructure, utility, and green-service gaps. The rank-gap and 180-specification multiverse checks distinguish stable extreme cases from contingent middle cases.

The broader lesson is methodological. Urban sustainability studies should not ask whether two composite systems are coordinated until they have shown that the systems are distinct. For Hebei, the policy issue is not whether economic development and resilience can be made to produce a high coupling score. It is where economic development and the measured public-service, infrastructure, utility, and ecological capacities occupy different relative positions. Because this bounded index excludes governance, social capital, emergency response, hazard exposure, and institutional adaptation, the mismatch is a diagnostic rather than evidence of causal conversion failure or comprehensive urban resilience.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18157637/s1>, Supplementary Table S1: Indicator definitions, transformations, weights, and source families. Supplementary Table S2: The top three obstacle indicators by Hebei city. Supplementary Table S3: The full descriptive statistics, and Supplementary Table S4: The Hebei annual mean trajectory values moved out of the main text.

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